Maricopa Association of Governments

2007 MAG Regional Travel Time & Travel Speed Study

Prepared for:

Maricopa Association of Governments
302 N. 1st Avenue, STE 300
Phoenix, AZ 85003

Prepared by:

7950 Elmbrook Drive
Dallas, Texas 75247-4951

April 18, 2008

Project Number 024212

Table of Contents

Page No.

List of Tables

Page No.

List of Figures

1.0 Executive Summary

1.1 Study Purpose

It is necessary for metropolitan planning organizations (MPO) to maintain an accurate, up to date regional transportation model in order to conform with State and Federal regulations for air quality and conduct regional transportation planning and travel forecasting for transportation projects. MPO's update, validate, and calibrate their models using current information on the roadway network, area development, and other relevant characteristics such as travel time and speed data. The Maricopa Association of Governments (MAG) updates their travel time and speed data periodically. Updates historically have been completed since the 1950's including the most recent one in 2002-2003.

The 2007 Regional Travel Time & Speed Study is aimed at the above purposes. It is also designed to compare this year's data with data from previous years to identify trends in congestion and travel time in order to identify problem locations for possible improvements. The project specifications developed by MAG produced the largest travel study in the country by covering over 70,000 miles of runs over the 2,038 centerline miles in the region. The centerline miles covered has grown each year to accommodate changes to the network.

1.2 Study Method

The 2007 Regional Travel Time & Speed Study was conducted using the floating car method as in previous studies, but with enhancements to the data collection, data management, and analytical methods. The study was conducted so that results could be compared with the results of the 1979, 1986, 1993, 2002-2003 Travel Time Studies in order to identify trends and changes in the roadway network and characteristics.

The roadways were mapped to establish centerlines and record relevant roadway features. Features located in the mapping process included: speed limits, school zones limits, and intersection control. Other elements were added using reference materials provided by MAG. Those include: area type, facility type, intersection geometry (historic and aerial), and city limits (Municipal Planning Area boundary).

Table 1 summarizes the number of miles driven in each jurisdiction during each period.

Table 1 – Miles by Jurisdiction

Jurisdiction	Directional Miles	AM Miles	MD Miles	PM Miles	Total Miles	Percent Covered
Apache Junction	43.0	211.6	118.3	338.9	668.7	0.9%
Avondale	41.1	262.2	142.0	245.8	650.0	0.9%
Buckeye	18.1	158.6	78.2	171.9	408.7	0.6%
Carefree	3.0	11.9	10.4	20.8	43.1	0.1%
Cave Creek	2.8	11.8	8.3	15.5	35.6	0.1%
Chandler	265.5	2010.4	960.0	1783.1	4753.5	6.6%
El Mirage	16.2	79.3	54.7	78.2	212.2	0.3%
Fountain Hills	8.0	39.9	23.9	39.9	103.8	0.1%
Gilbert	231.9	1531.2	862.9	1510.5	3904.6	5.4%
Glendale	227.3	1587.3	722.0	1574.2	3883.5	5.4%
Goodyear	58.4	383.6	200.6	385.1	969.3	1.3%
Guadalupe	9.0	79.3	23.8	105.3	208.3	0.3%
Litchfield Park	3.2	12.9	9.7	14.5	37.1	0.1%
Maricopa County	565.2	3155.8	1800.7	3402.6	8359.1	11.6%
Mesa	410.6	3302.2	1342.8	3454.1	8099.1	11.3%
Paradise Valley	30.4	256.9	101.3	248.9	607.0	0.8%
Peoria	129.9	970.1	418.7	925.3	2314.1	3.2%
Phoenix	1440.1	11221.1	4254.0	10952.0	26427.1	36.8%
Pinal County	15.9	159.2	61.7	185.6	406.4	0.6%
Queen Creek	4.0	15.0	14.0	16.0	45.0	0.1%
Scottsdale	272.1	1871.7	884.0	1819.3	4575.0	6.4%
Surprise	46.5	241.4	139.4	223.0	603.8	0.8%
Tempe	220.0	1791.6	653.9	1870.6	4316.1	6.0%
Tolleson	11.5	93.0	35.2	82.0	210.2	0.3%
Total	4073.5	29457.9	12920.5	29462.9	71841.4	100.0%

Notes:
Directional miles include both directions and are based on centerline miles provided by MAG (February 13, 2008).
Miles are total driven directional miles surveyed for travel time runs.

Travel speed data was collected from February 2007 through January 2008 on Tuesdays, Wednesdays, and Thursdays, during the morning and afternoon peak, and during the midday off-peak period as follows:

- Morning Peak Period: 6:30 to 8:30 AM
- Midday Off-Peak Period: 9:00 to 11:00 AM
- Afternoon Peak Period: 4:00 to 6:00 PM

Roadways included arterials, freeways, and HOV lanes. On average, there were a total of 19 runs in each direction (8 in each direction in the AM/PM peak and 3 in the midday) on each roadway included in the study with 30-minute headways to show variation during the peak periods. The number of runs was assigned by MAG.

The power of the data collected is that it can be displayed in detail in a variety of forms in both figures and tables. It can be shown in its' raw form as in **Figure 1** that includes

the 1-second points from the travel time runs. Summarizing the data between each intersection for each run produces values for speed as shown in **Figure 2**. This figure demonstrates the variability of the speed over the 2-hour time period. By averaging all runs together within each segment for each of the time periods (AM, midday, and PM), a summary of the data is produced as shown in **Figure 3**. At times, it is desired to determine how much below the posted speed the resulting average segment speed is. By comparing the resulting average speed to the coded speed limits, the % of posted speed is displayed as shown in **Figure 4**. This is a useful measure of effectiveness (MOE), but since the length of each segment varies, it sometimes indicates longer delays on the shorter segments. This is due to the longer segments having more time to dilute delays that may have occurred. To address this element, an additional MOE was implemented that utilized a common unit of length so that all segments were compared on an even plane.

Figure 1 – 1-Second GPS Points Detail

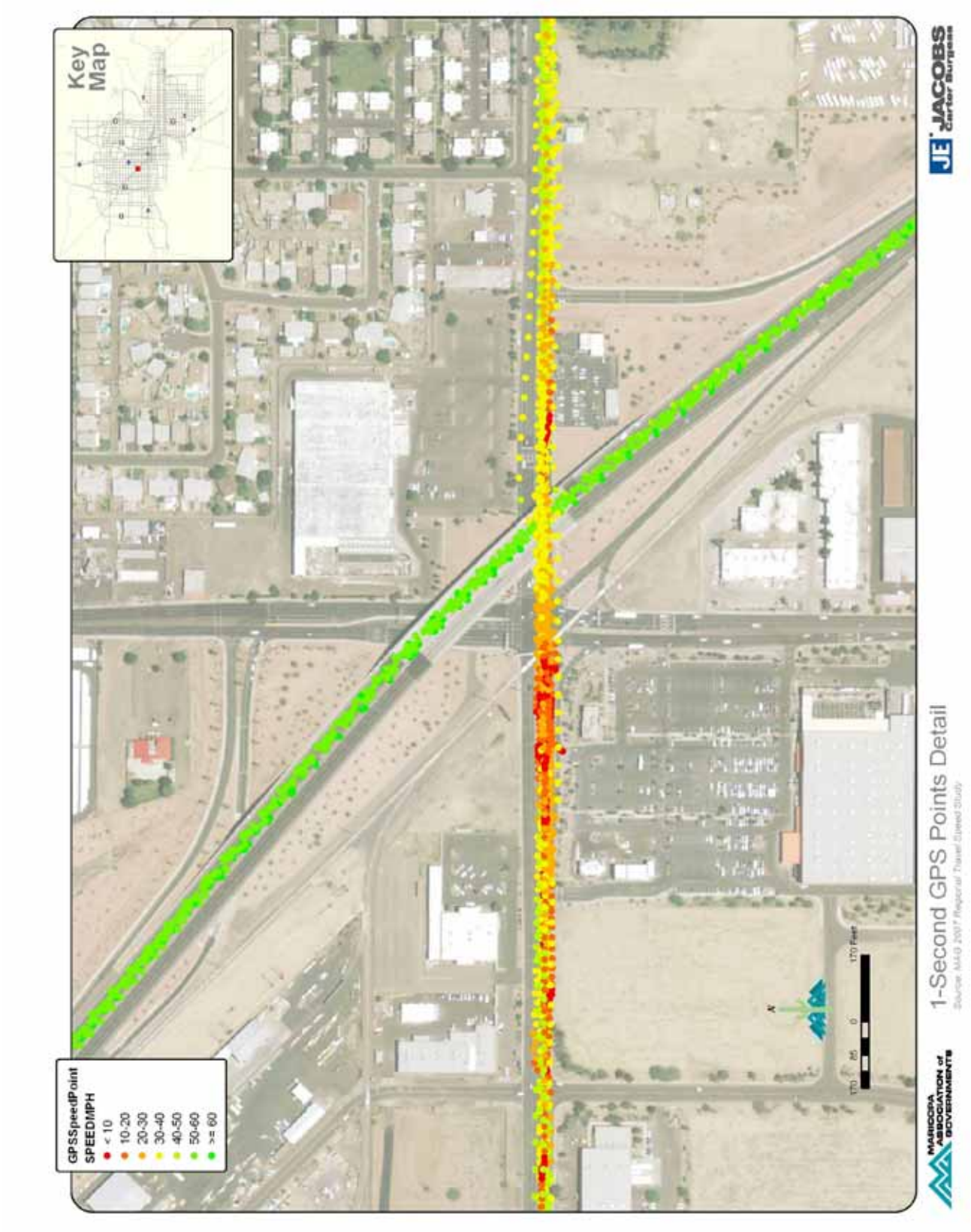


Figure 2 – Average Arterial Speed by 30-Minute Time Period - PM

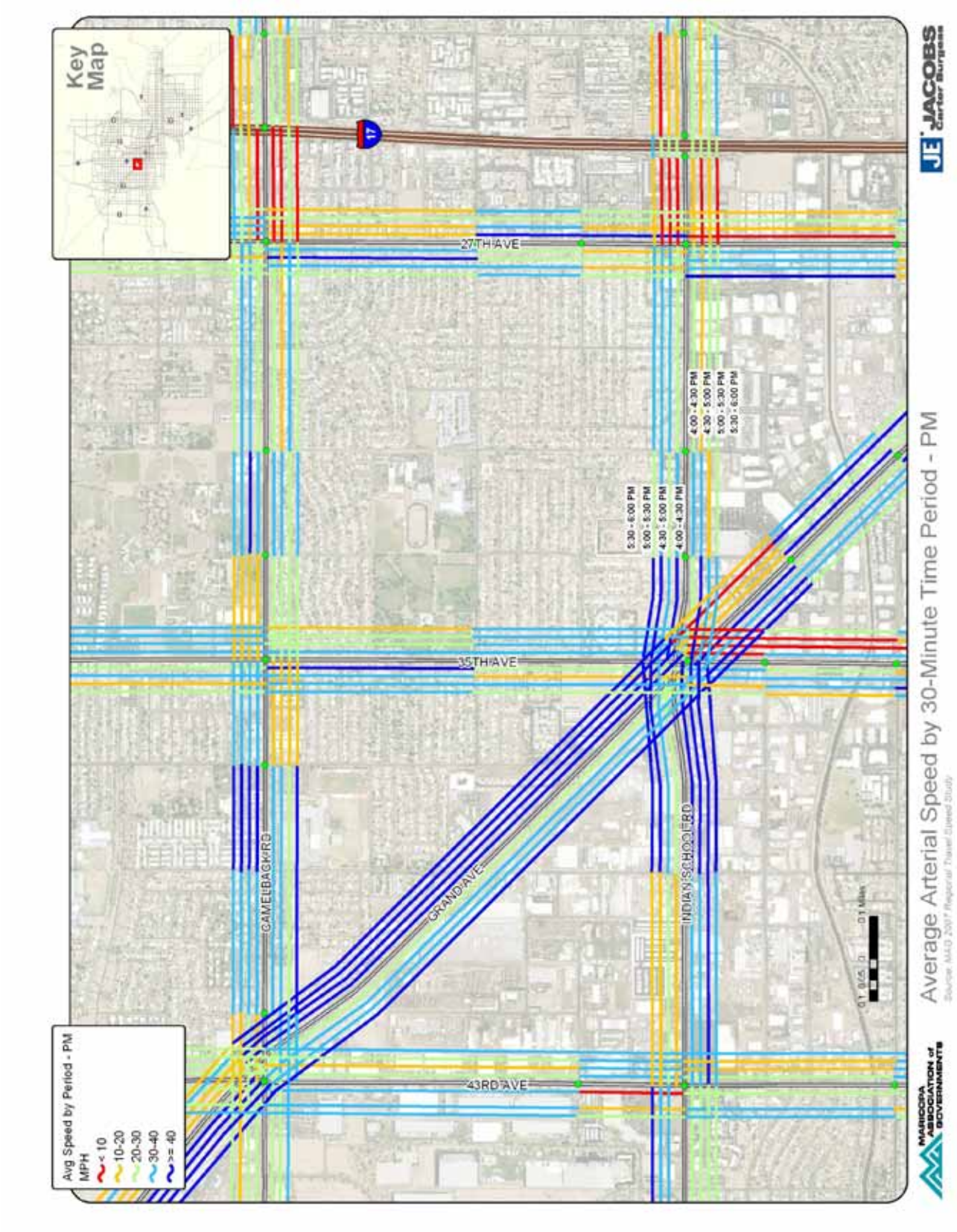


Figure 3 – Average Arterial Speed – PM (Detail)

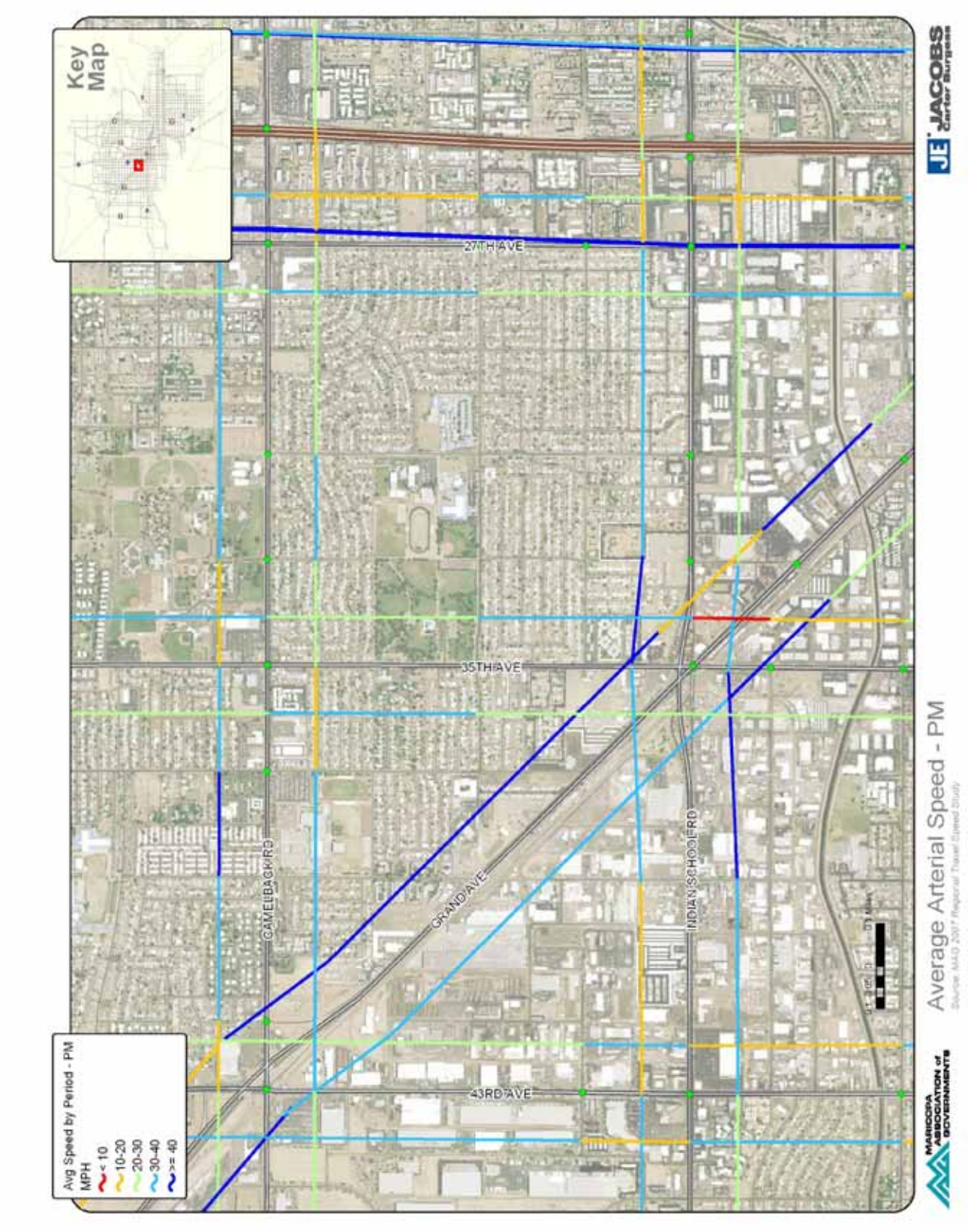
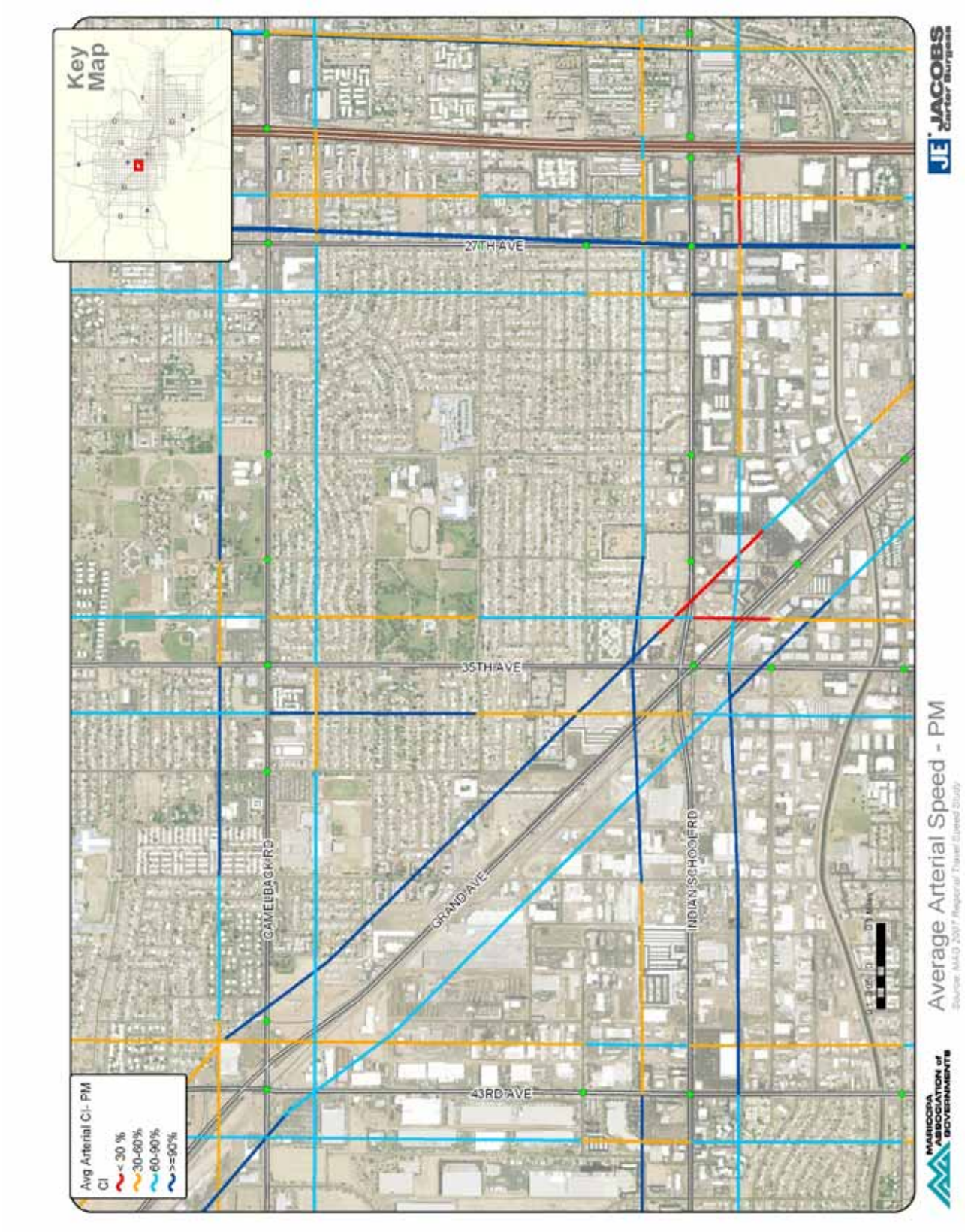


Figure 4 – Average Percent Posted Speed – PM (Detail)



1.3 Study Results

Figures 5 and **6** illustrate the resulting average speed by jurisdiction for arterials and freeways, respectively. Only those jurisdictions with functionally classified freeways are included in **Figure 6**.

In order to differentiate between congested roadways and roadways with low speed limits, an additional method for illustrating the data was incorporated into the 2007 Regional Travel Time & Speed Study. This method uses a ratio of actual travel speed to posted speed limit and is referred to as the Percent Posted Speed (see discussion in section 3.3.). The average arterial and freeway Percent Posted Speed by jurisdiction is shown on **Figures 7** and **8**. Only those jurisdictions with functionally classified freeways are included in Figure 8. The most common method used to determine speed within a segment is space mean speed (SMS). SMS is calculated by dividing the distance traveled by the time to traverse the segment.

Figure 5 – Average Arterial Speed by Jurisdiction

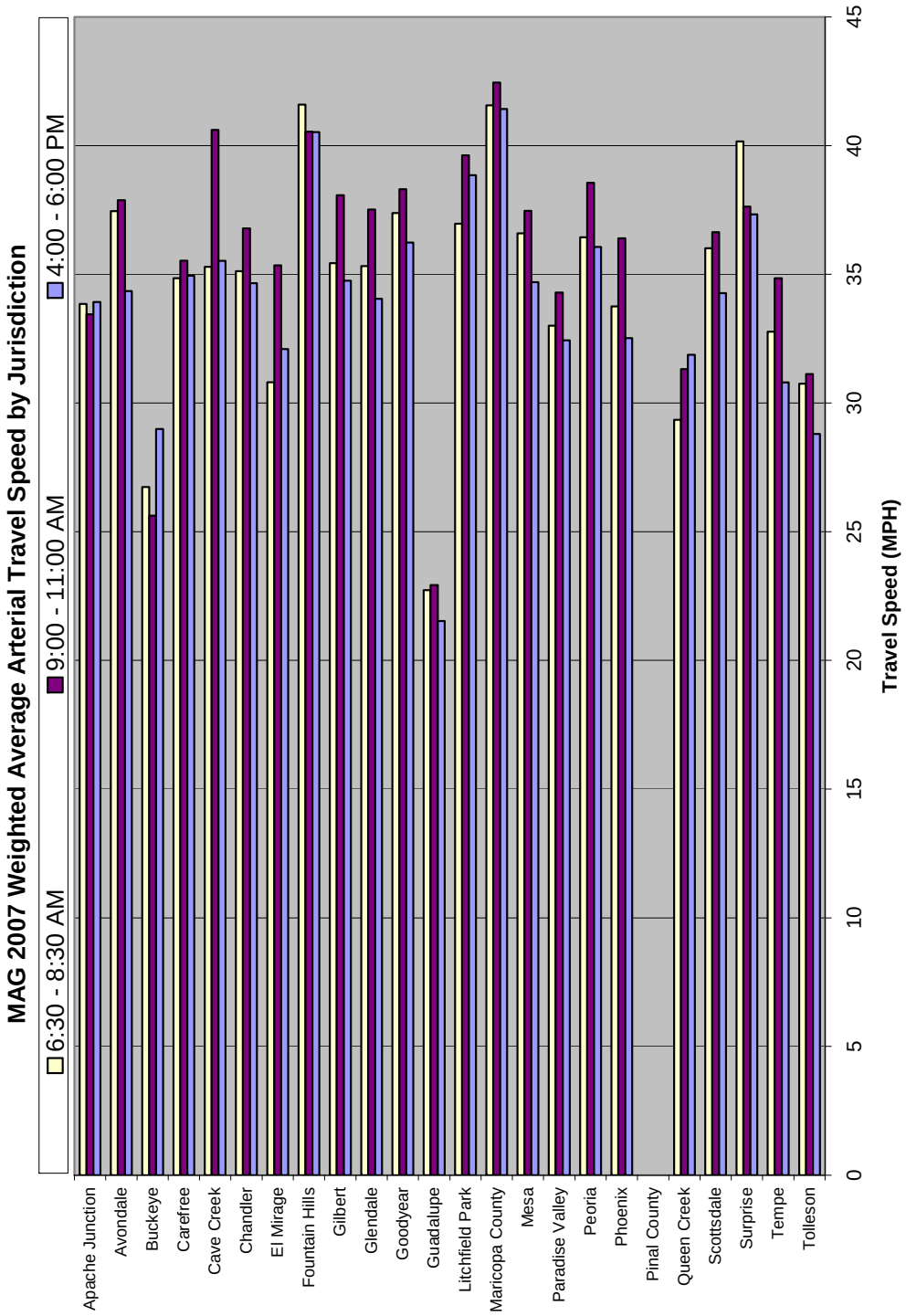


Figure 6 - Average Freeway Speed by Jurisdiction

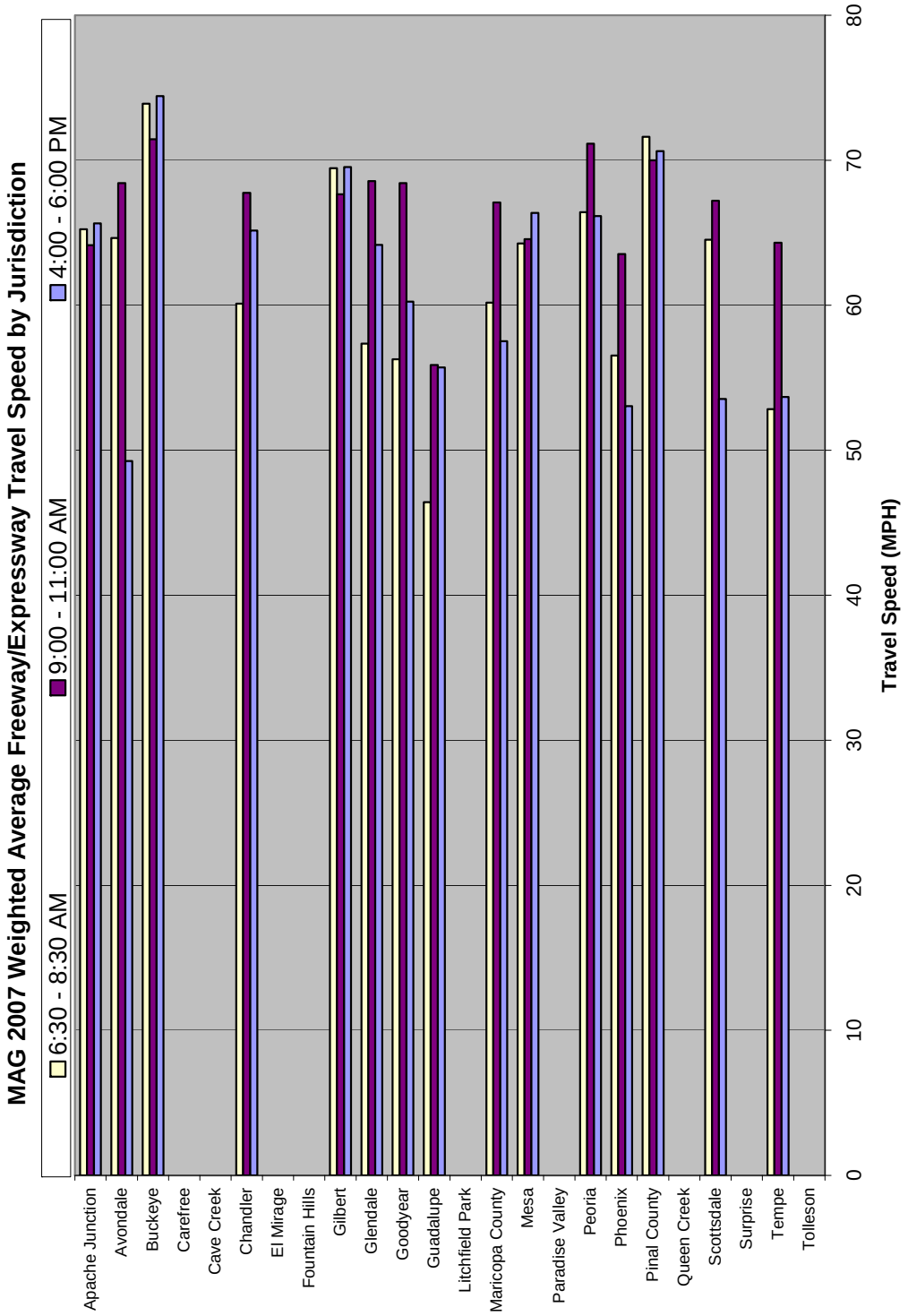


Figure 7 – Average Arterial % Posted Speed by Jurisdiction

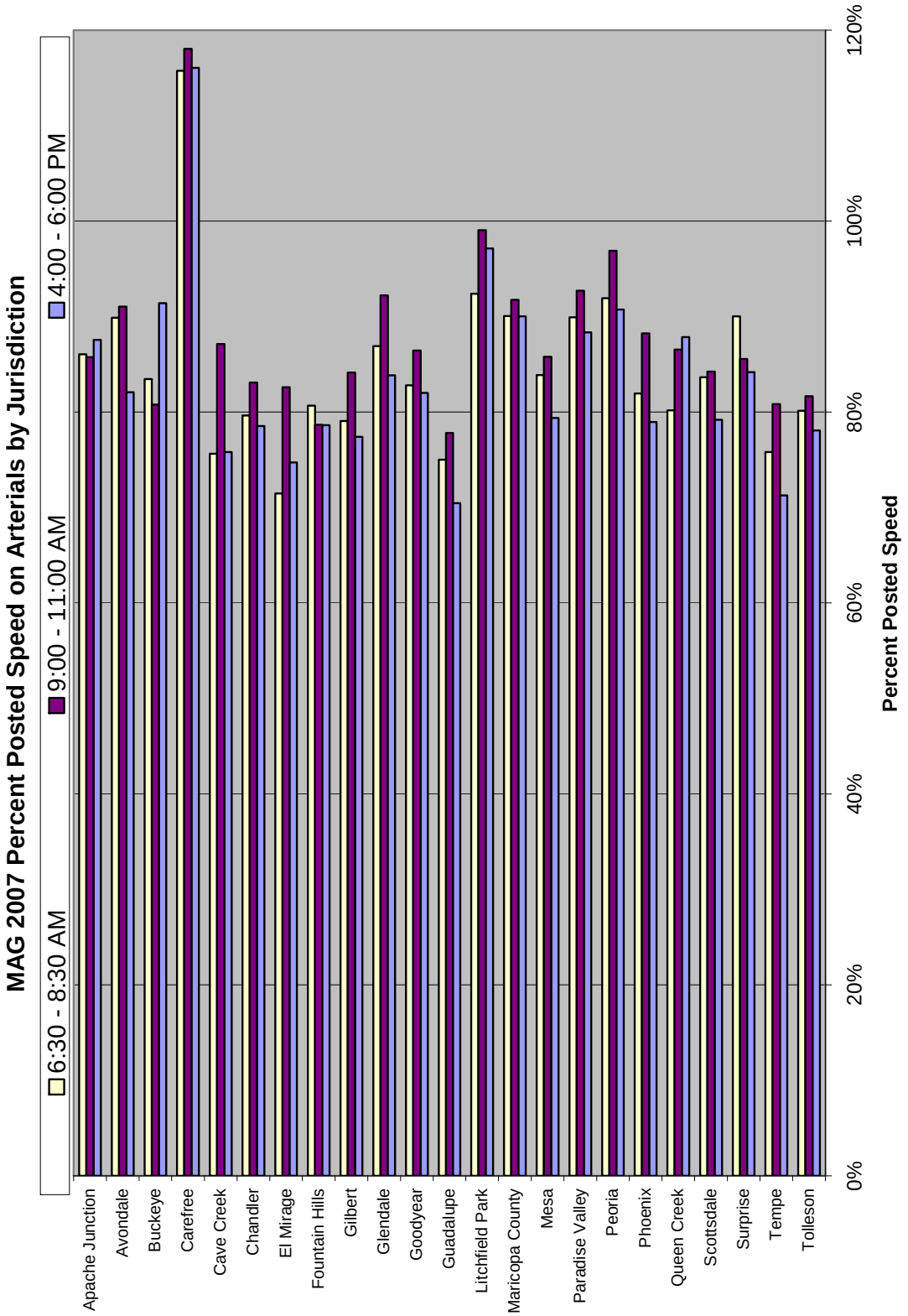


Figure 8 – Average Freeway % Posted Speed by Jurisdiction

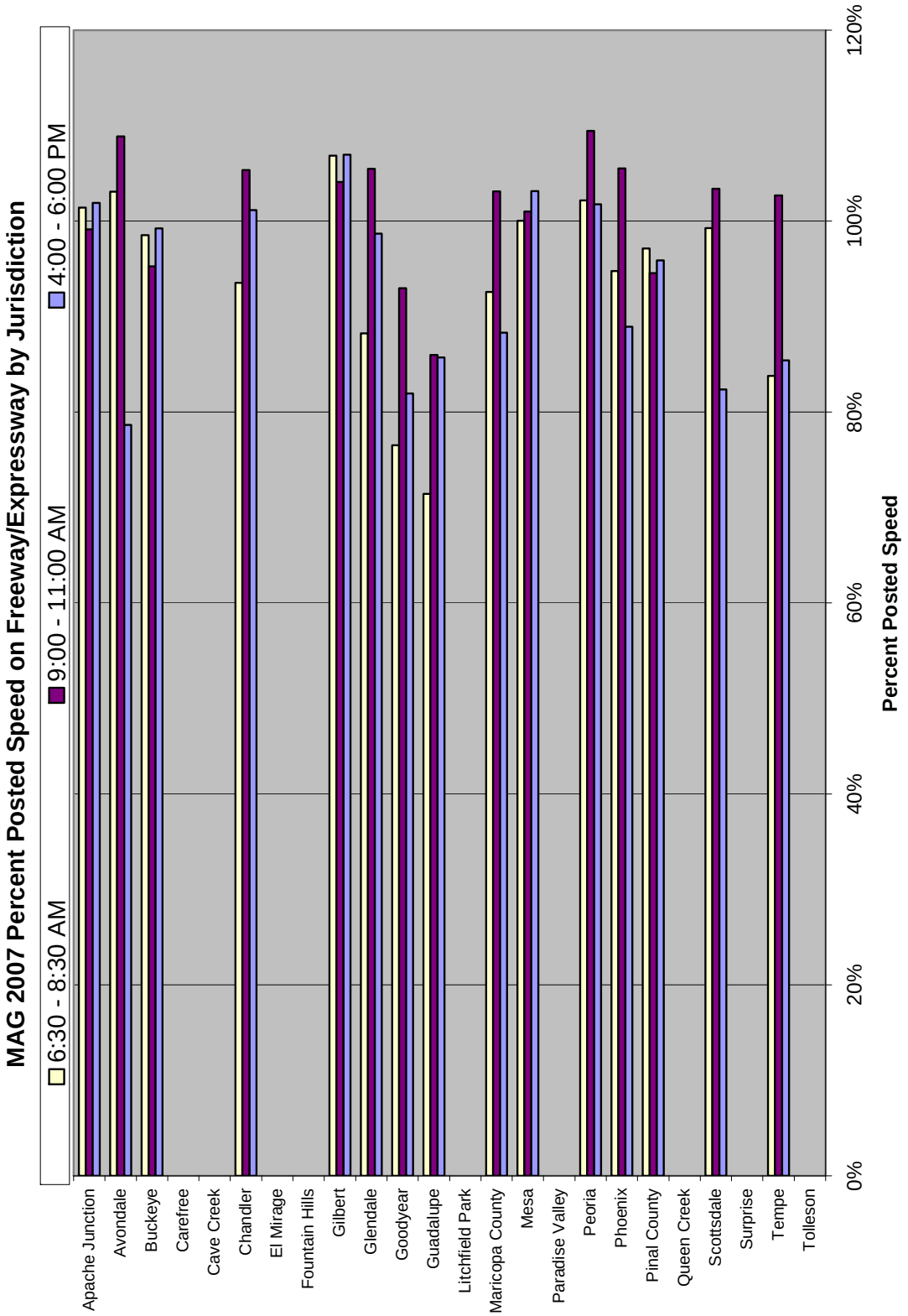


Figure 9 provide an overall summary for the average travel speed (weighted by distance) for all arterials and freeways included in the 2007 study. It illustrates the speeds on the arterials vary by about 3 mph through the day and the freeways have a range of approximately 5 mph. Similarly, **Figure 10** shows the average Percent Posted Speed for the same facilities.

Figure 9 - Average Travel Speeds

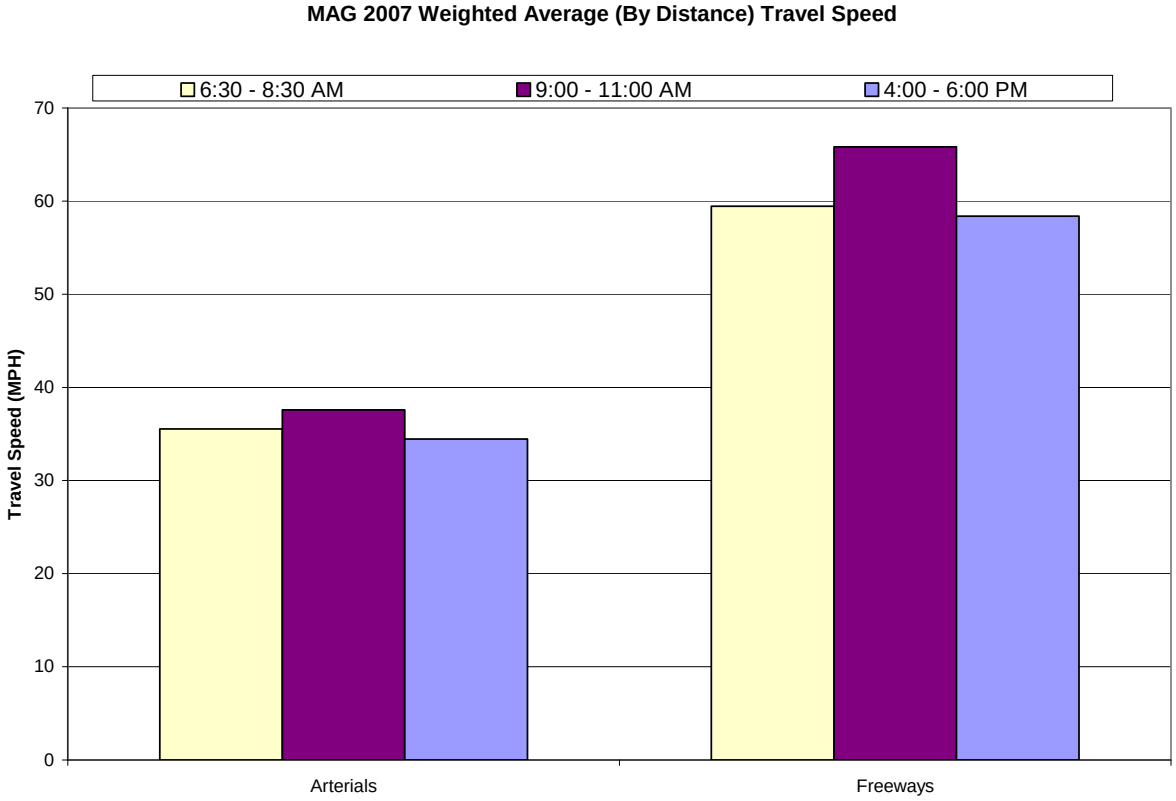
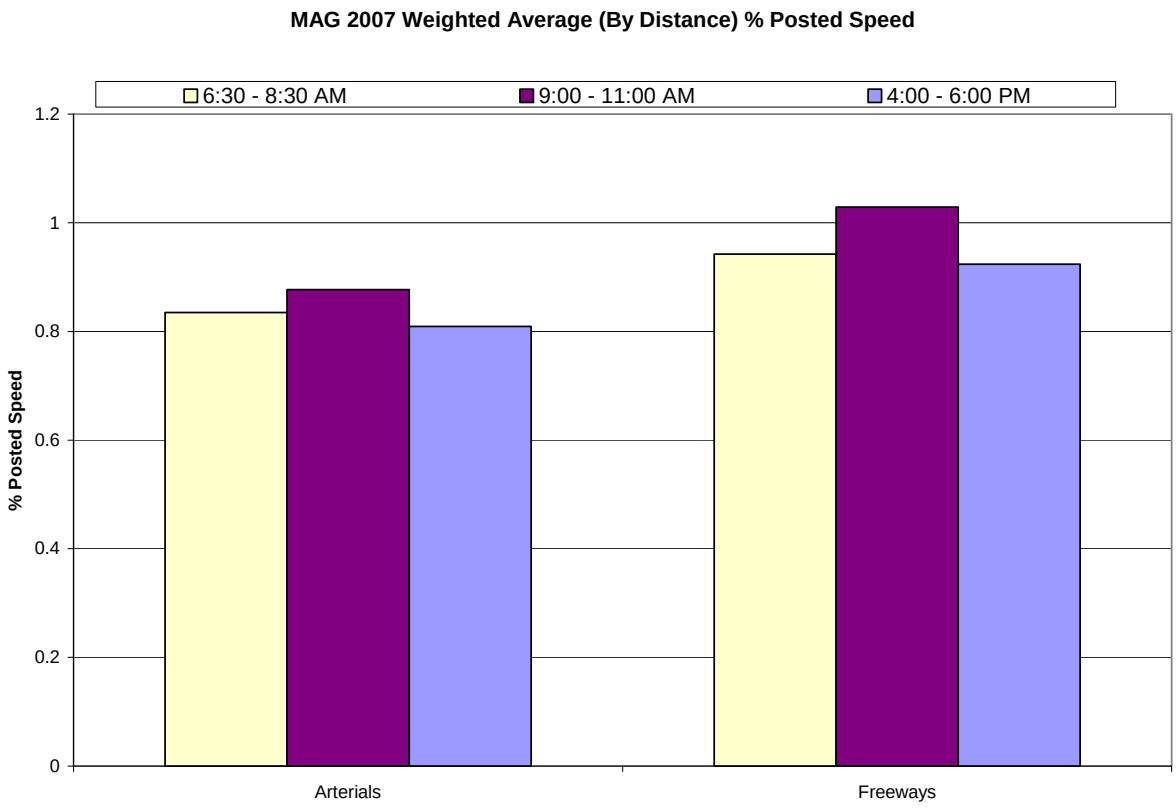


Figure 10 – Average % Posted Speed



2.0 Introduction

It is necessary for metropolitan planning organizations (MPO) to maintain an accurate, up to date regional transportation model in order to conform with State and Federal regulations for air quality and transportation projects. MPO's update and calibrate their models using current information on the roadway network, area development, and other relevant characteristics. The Maricopa Association of Governments updates their travel time and speed data periodically.

The primary purpose of this year's 2007 Regional Travel Time & Speed Study was to compare this year's data with data from previous years to identify trends in congestion and travel time in order to identify problem locations for possible improvements.

The 2007 Regional Travel Time & Speed Study data can be used for a variety of additional uses. With the travel speed information organized in a GIS system including other data such as facility and area type, number of lanes, etc., queries can group data by city for use in individual planning processes. The database can be used for background information for street improvements, signal timing, signing and pavement marking, school zone issues, and other transportation related projects.

The following report describes the 2007 Regional Travel Time & Speed Study.

- Section 3 focuses on the methodology and includes a set of assumptions, definitions for terms used throughout the report, the method for route selection, and the process used to actually collect and manipulate the travel speed data. Information is provided regarding quality control, data analysis, data aggregation, and problems encountered during the data collection process.
- Section 4 documents the results of the data collection showing various aggregations such as travel speeds by functional class, travel speed by jurisdiction, and other relevant combinations.
- Section 5 focuses on intersection delay.
- Section 6 documents the historical trends and changes in travel speeds and delays in the regions.

3.0 Methodology

This section details the approach followed including the selection of routes, data collection equipment and training, mapping, travel time periods, quality control, data analysis, summary of data, and problems encountered.

3.1 Definitions and Data Dictionary

Several terms are used throughout this report and are defined here for clarification. See data dictionary (Appendix B) for complete list.

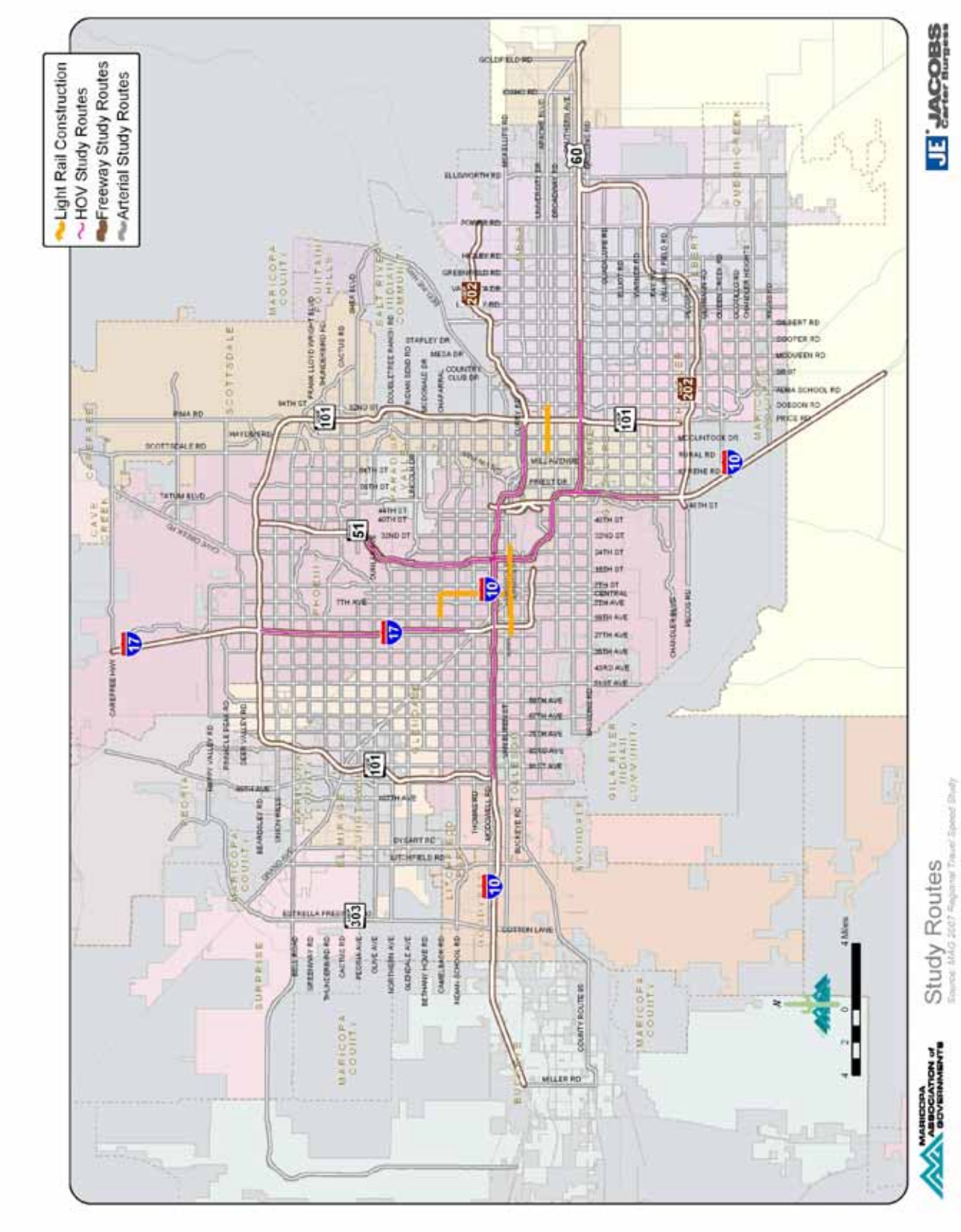
Table 2 – Glossary

Term	Definition
Afternoon Peak Period (PM)	The time period from 4:00 PM to 6:00 PM on a typical weekday
Segment Delay	The difference between travel time at posted speed limit and actual travel time from one intersection to the next intersection
Observed Queue Length	This is the distance between the test vehicle and the intersection from the point where the speed of the test vehicle drops below 3 mph.
Percent Posted Speed	The ratio of the actual speed to the posted speed limit.
Control Delay	Stopped delay times 1.30 (see Sec 5.1)
Free Flow Speed	Speed Limit or weighted average speed limit. Weighted by length of speed zones where the speed limit changes between intersections.
Mean Running Speed	Speed calculate from the time the vehicle is traveling at > 3 MPH
Mean Travel Speed	The distance divided by the mean travel time of several trips.
Measure of Effectiveness	Performance measures such as delay, LOS, % Posted Speed, etc.
Midday Off Peak Period (MD)	The time period from 9:00 AM to 11:00 AM on a typical weekday
Morning Peak Period (AM)	The time period from 6:30 AM to 8:30 AM on a typical weekday
Peak Period	Two hour time period
Route ID	The number designated to each route
Space Mean Speed	Speed calculated from the distance traveled over the time to travel that distance
Spot Speed	The instantaneous measure of speed at a specific location on a roadway.
Stopped Delay	Number of seconds a vehicle is below 3mph with a given segment.
Theoretical Travel Time	Time it takes for a vehicle to travel a given section of roadway at the posted speed limit.
Time Mean Speed	The arithmetic average of 1 second GPS speed within the segment.
Time Period	30-minute time interval within two hour peak periods (AM, MD, and PM)

3.2 Route Selection

The 2007 Regional Travel Time & Speed Study included most of the higher volume arterials and all freeways/HOV lanes within the study area. The included routes are shown in **Figure 11**. All signalized intersections on these routes were included in the study for delay calculations as well. All roadways included in previous studies were included as well as additional roadways. The additional routes for the 2007 effort were primarily extensions or previous routes or new routes along the perimeter of the region.

Figure 11 - Study Routes



3.3 Project Methodology

As before, the 2007 Regional Travel Time & Speed Study included travel time studies with the floating car method and the enhanced data collection, data management, and analytical methods similar to the 2002-2003 study. The study was conducted so that results could be compared with the historical results of the 1979, 1986, 1993, and 2002-2003 Travel Time Studies in order to identify trends and changes in the roadway network and characteristics; however, additional data and advancements in data collection methods allowed for more detailed traditional analyses as well as analyses that had previously not been performed.

First, the additional routes roadways were mapped to establish centerlines and record relevant roadway features. The geographic information system (GIS) utilizes a linear reference system (LRS) for the basis of all roadway and travel speed data. Features and data within a linear reference system use position along a route instead of a x,y coordinate system. The route features contain measures or distance along the route. For this travel time study the route network contains all streets included in the study. Details and illustrations of the LRS are included in Appendix B. After mapping all routes, the travel time runs were collected. Details on the data collection are found in the following section.

A 30-minute headway was used between each run in order to document speed variation over the two-hour morning and afternoon peak periods. Intersection delay was calculated for all signalized intersections within the study area. Delay calculations were provided for through vehicles only. No analyses were conducted for turning movements. The delay in seconds was then compared with the *Highway Capacity Manual*, Transportation Research Board, 2000, Exhibit 16-2, criteria for level of service (LOS) for signalized intersections. These criteria categorize vehicle delay into levels of service ranging from LOS A, meaning less than or equal to 10 seconds of delay, to LOS F, meaning more than 80 seconds of delay.

The location of the survey vehicle in the queue of a controlled intersection was measured for each approach of each intersection. A test vehicle was determined to be in a queue if the speed of the vehicle dropped below 3 mph. The test vehicle may not have been the last vehicle in the queue, since additional cars could have joined the queue after the test vehicle. Because of this, the measured average queue length was determined from the various runs in each time period to be used as a representative measure.

Previous travel time studies documented the observed speed on roadways without regard to the posted speed limit. This method may indicate slow speeds when in reality, traffic may be traveling according to a low posted speed limit. In order to differentiate between congested roadways and roadways with low speed limits, a new method for illustrating the data was incorporated into the 2002-2003 Travel Speed Study. This method used a ratio of actual travel speed to posted speed limit called the Percent Posted Speed. If it is 1.0 or greater, it indicates free flow speed, where traffic is traveling at the speed limit or higher. Municipalities can define levels of Percent Posted

Speed to indicate free flow, average flow, and congested flow. This information can be used in the planning process to better appropriate funds for needed improvements.

3.4 Data Collection

3.4.1 Equipment and Training

Mapping was conducted using a Trimble PRO-XRS GPS unit with real-time differentially corrected data and sub-meter accuracy. The GPS unit was attached to a test vehicle and roadway features were coded using software on a laptop computer.

Travel time runs were conducted using Haicom BT GPS. These units are significantly less expensive than the Trimble PRO-XRS and provide accuracy to 10-feet after being post-processed differentially corrected. The GPS data was collected and stored on personal data assistants (PDA) using Microsoft operating system and customized data management program.

The Jacobs Carter Burgess managers trained and rode with technicians on example routes. The training occurred over two days, and each technician was tested by the managers before being permitted to work on the project. Training consisted of an overview of the project, the equipment being used, the floating car method for travel time runs, and safety.

3.4.2 Procedure

The first step in the study process was to map the roadways using GPS equipment to establish centerlines and code relevant roadway features. Centerlines were mapped by driving in one direction and using an offset distance from the travel lane to code the centerline. Features documented in the mapping process included: intersection control (**Figure 12**), speed limits (**Figures 13 and 14**), number of lanes (**Figures 15 and 16**), school zones limits (see Appendix A), and construction areas. Other elements were coded in GIS using data provided by the MPO. Those included jurisdictional s (**Figure 17)**, area type (**Figure 18**), and facility type (**Figures 19, 20, and 21**). The area and facility type were used to compare similar roadways, speed limits and school zone speed limits were used to calculate the Percent Posted Speedto determine whether roadway segments were congested, intersection control was collected to supplement the GIS system, and construction areas were noted so that low speeds in these areas could be filtered. The City Limit lines were collected so that information could be organized by City.

Upon completion of the mapping, routes for the travel time runs were generated based on MAG's GIS-T network. These routes were updated (e.g. alignments, intersections, etc.) using the latest mapping data and available aerial photographs. Finally, travel time runs were performed. This information was used to calculate speeds and travel times.

For the 2007 Travel Speed Study, data was collected from February 2007 through January 2008. The data was collected on Tuesdays, Wednesdays, and Thursdays, during the morning and afternoon peak, and during the midday off-peak period. Runs were conducted on Tuesday through Thursday because they more consistently represent average conditions. Later in the project, runs were added for the Monday PM and Friday AM period to accelerate the schedule. The study time periods were as follows:

- Morning Peak Period: 6:30 to 8:30 AM
- Midday Off-Peak Period: 9:00 to 11:00 AM
- Afternoon Peak Period: 4:00 to 6:00 PM

Travel time runs were conducted using the floating car method, as was used in the previous studies. The floating car method is described in detail in the Manual of Traffic Engineering Studies published by the Institute of Transportation Engineers. The test vehicle travels within the flow of traffic, passing as many vehicles as pass the test vehicle. In this way, the test vehicle is representing the average vehicle speed.

Figure 12– Intersection Control

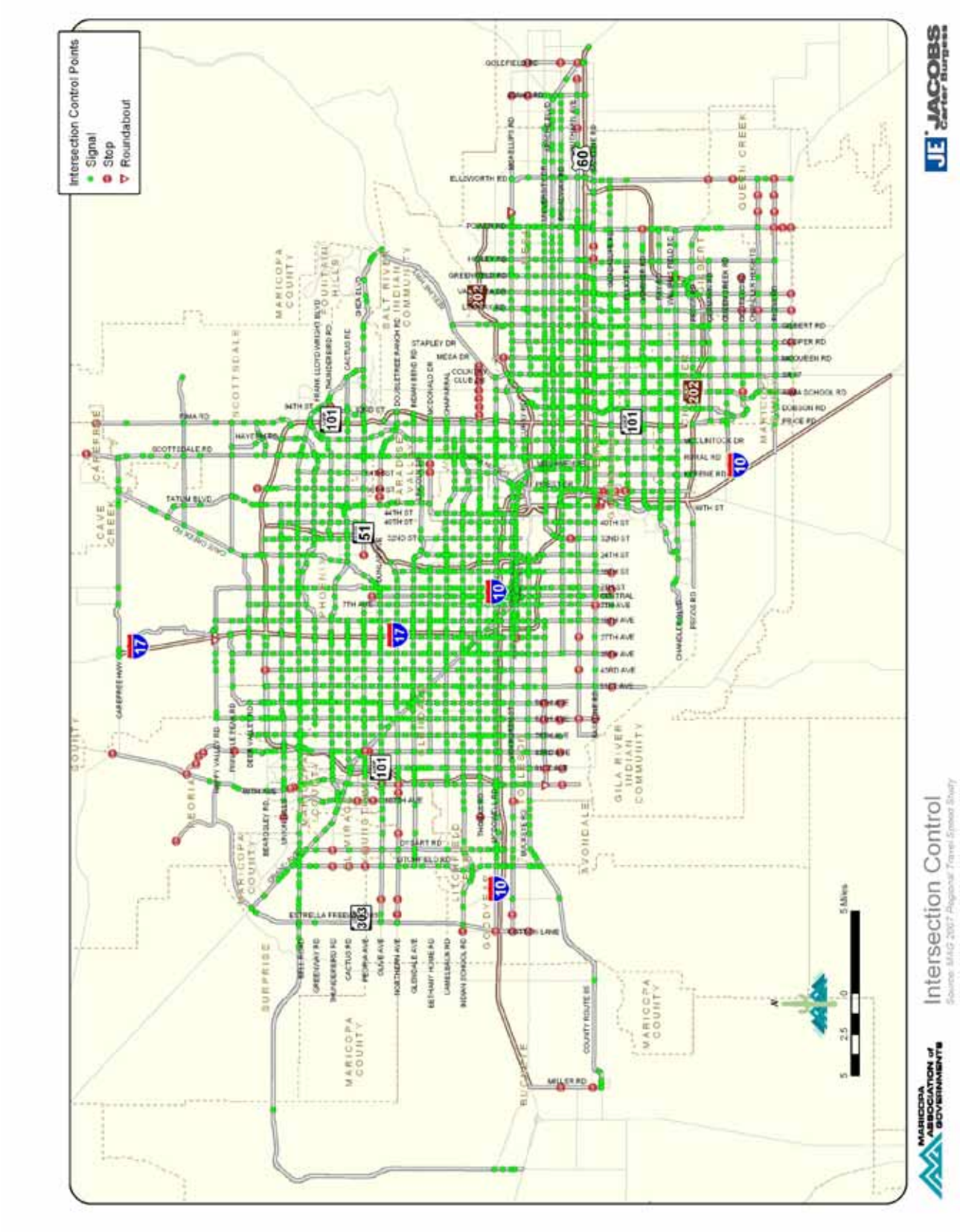


Figure 13 – Posted Arterial Speed Limits

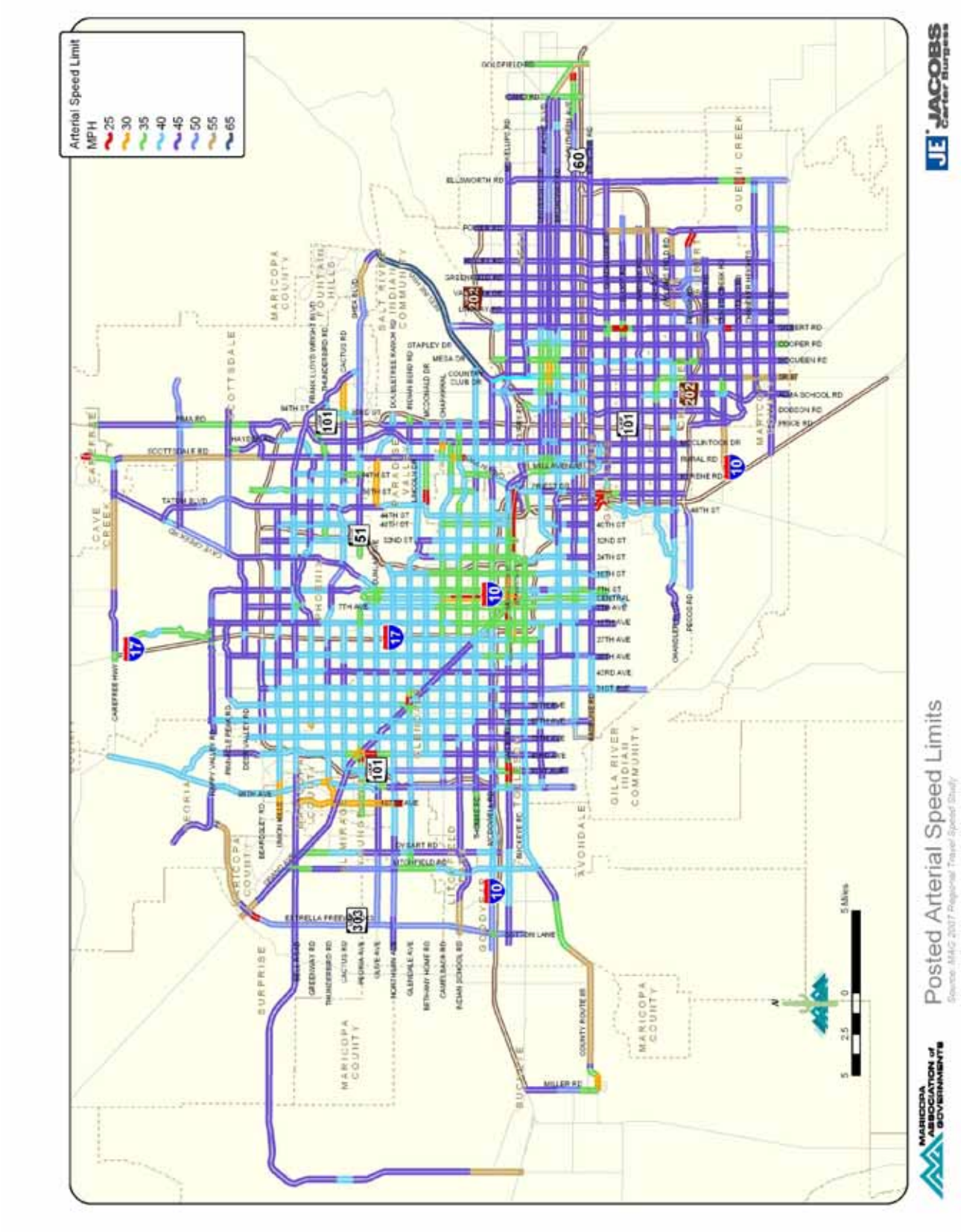


Figure 14 – Posted Freeway Speed Limits

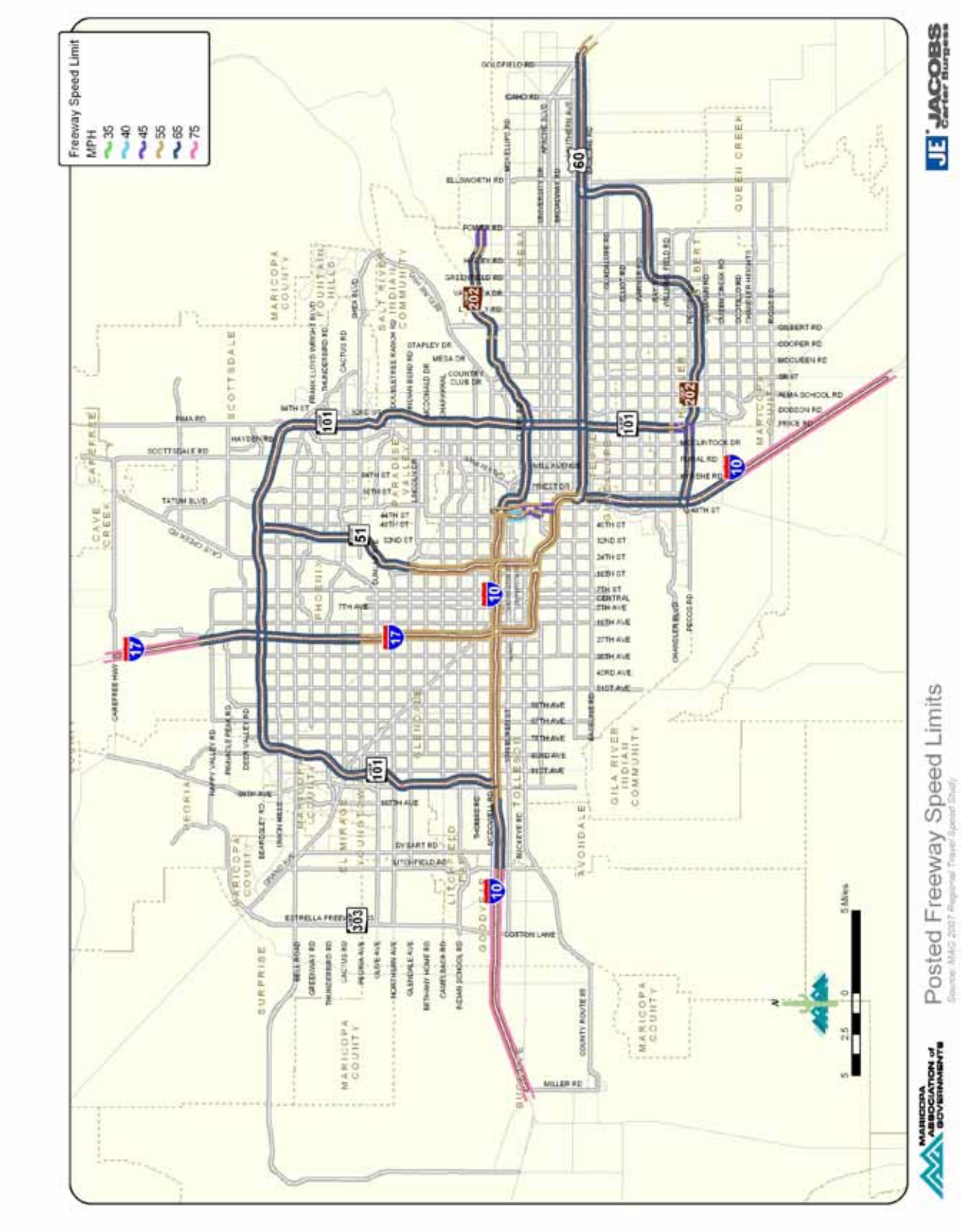


Figure 15 – Arterial Number of Lanes Each Direction

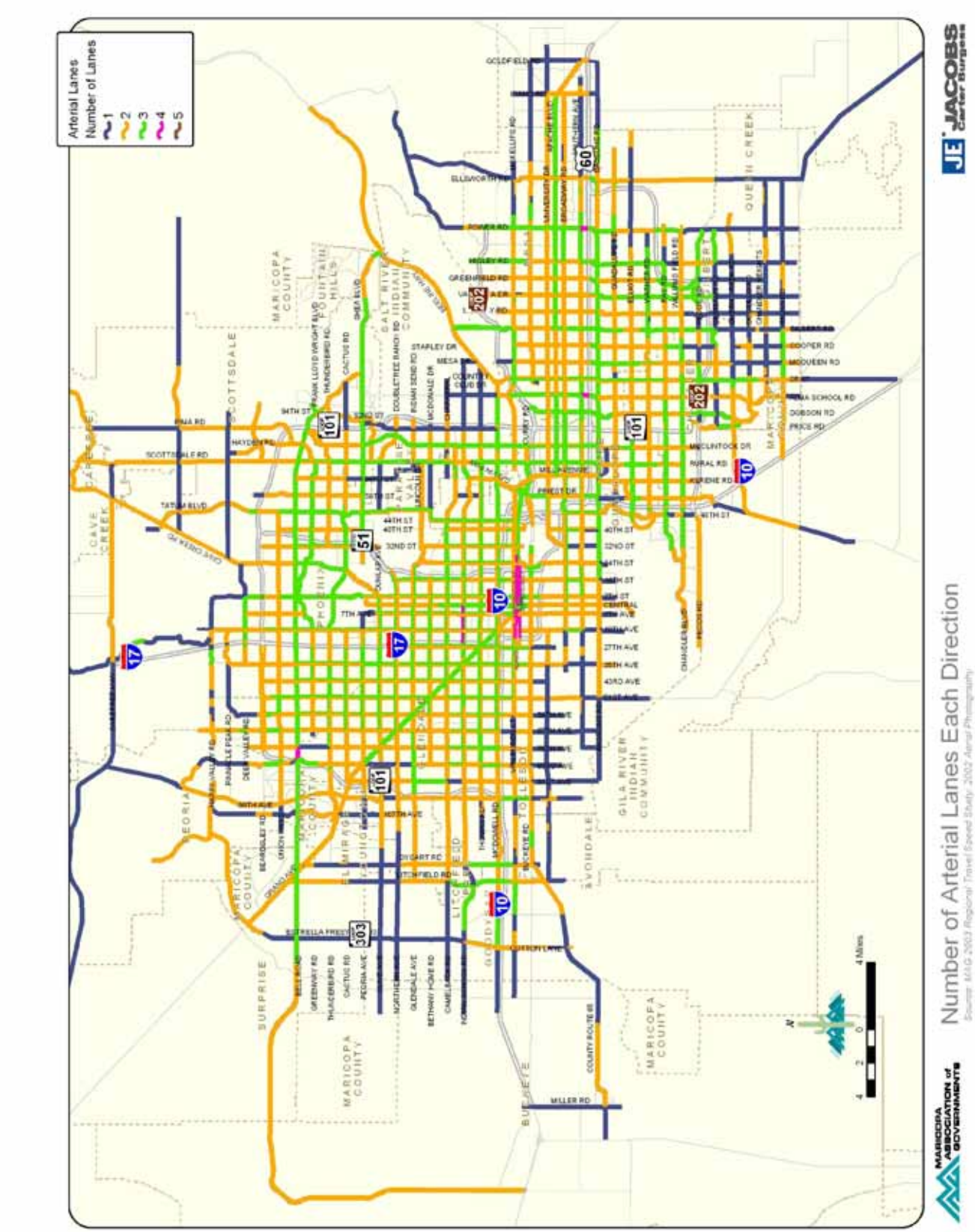


Figure 16 – Number of Freeway Lanes Each Direction

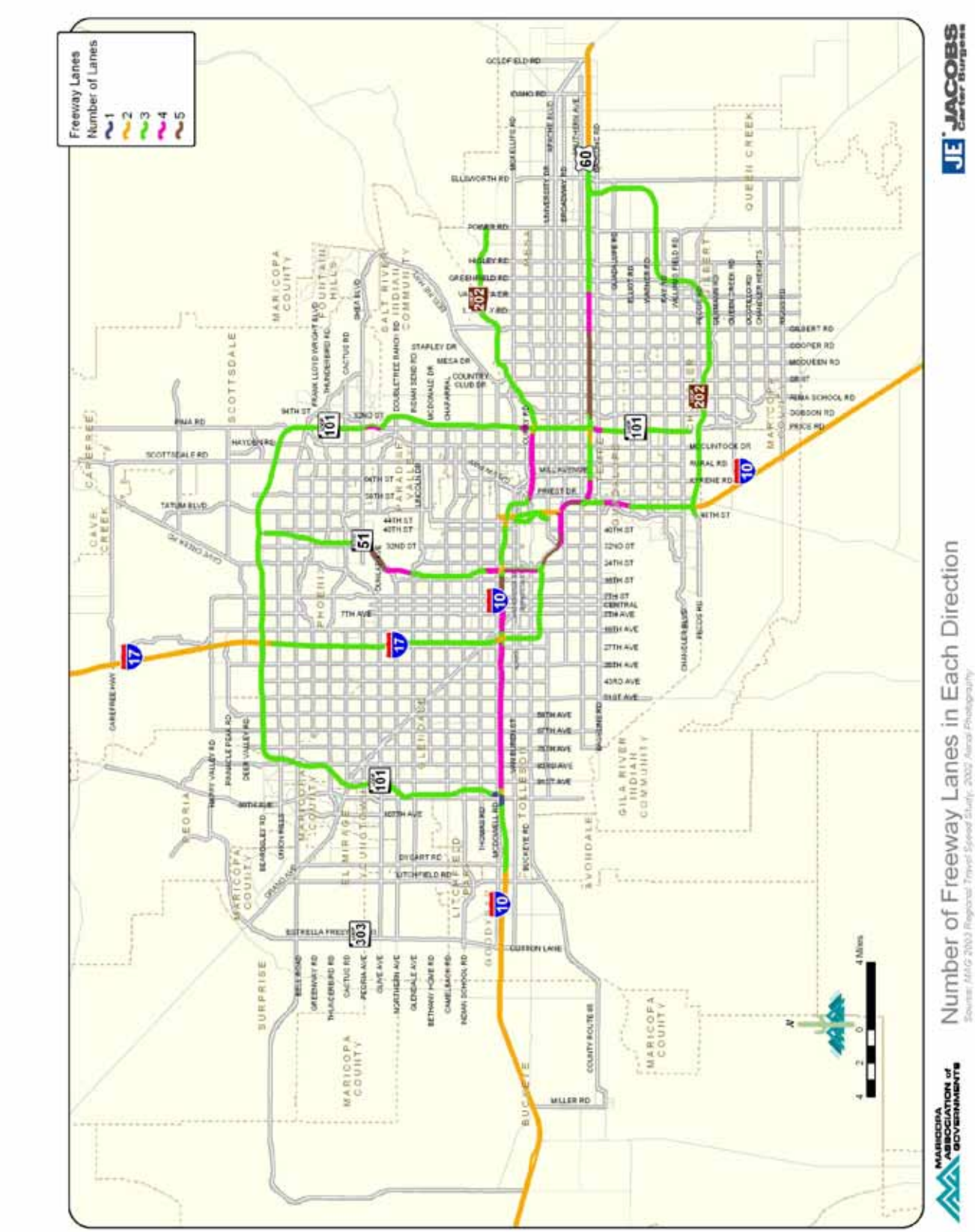


Figure 17 – Jurisdictional Segments

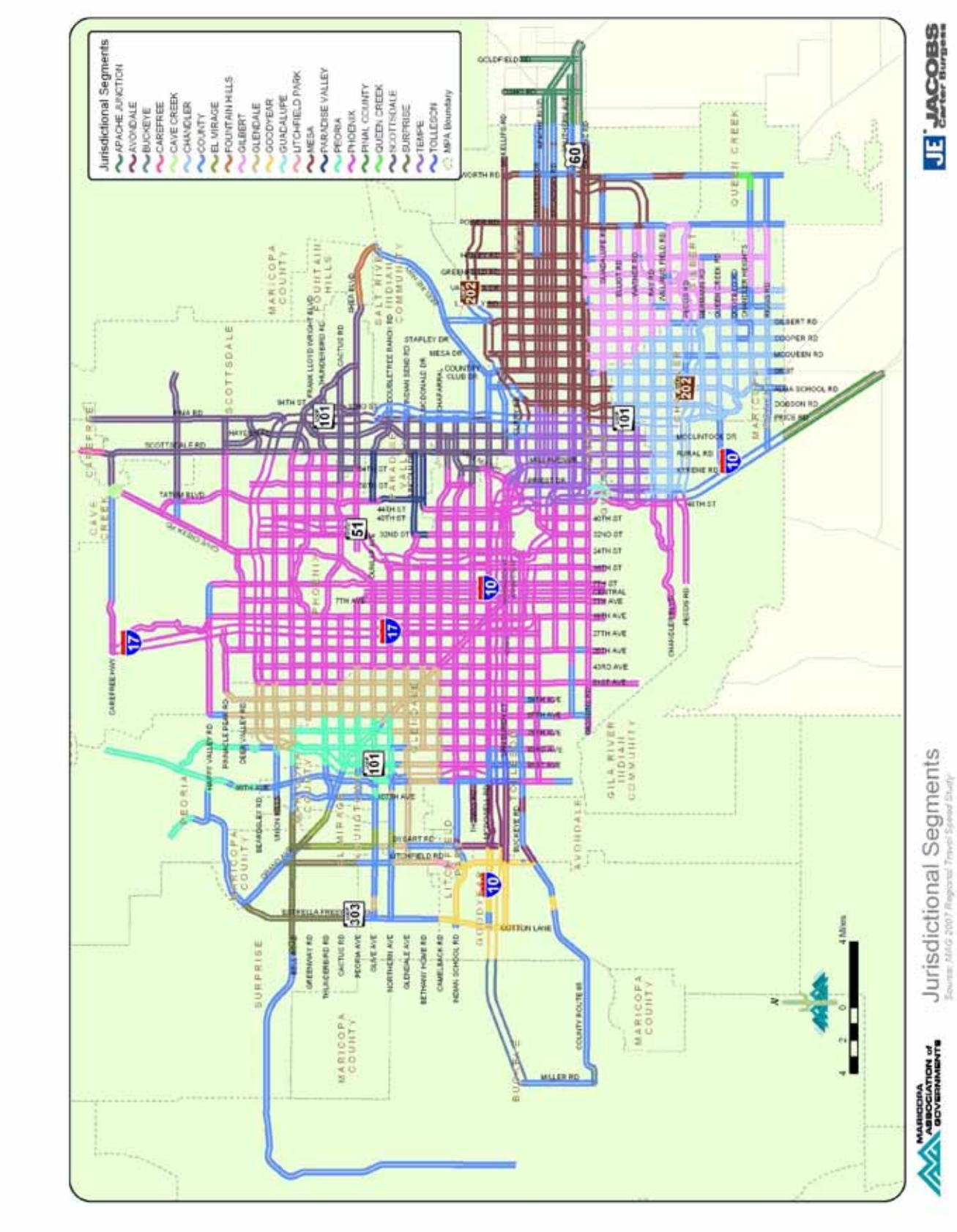


Figure 18 – Area Type

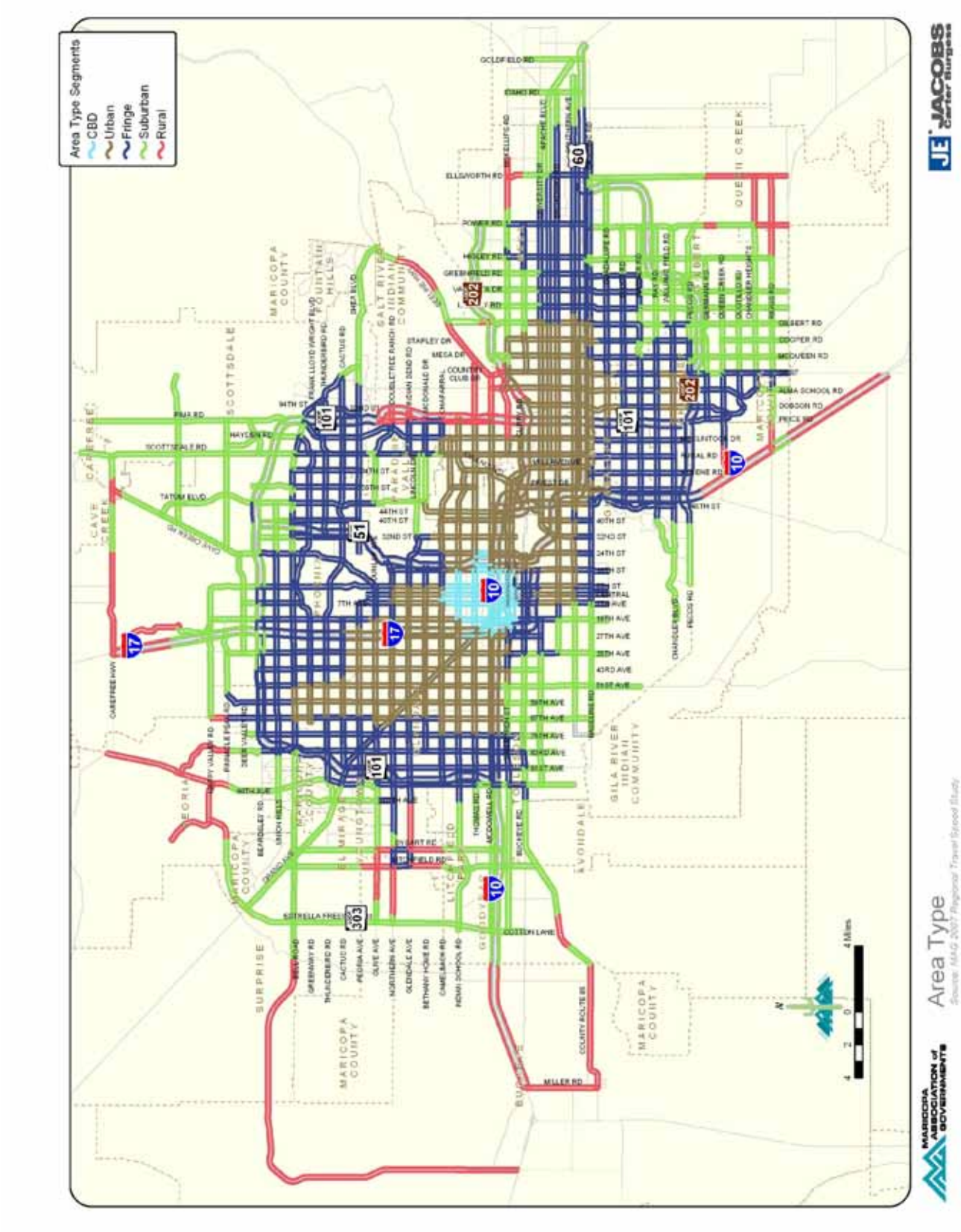


Figure 19 – Arterial Facility Type

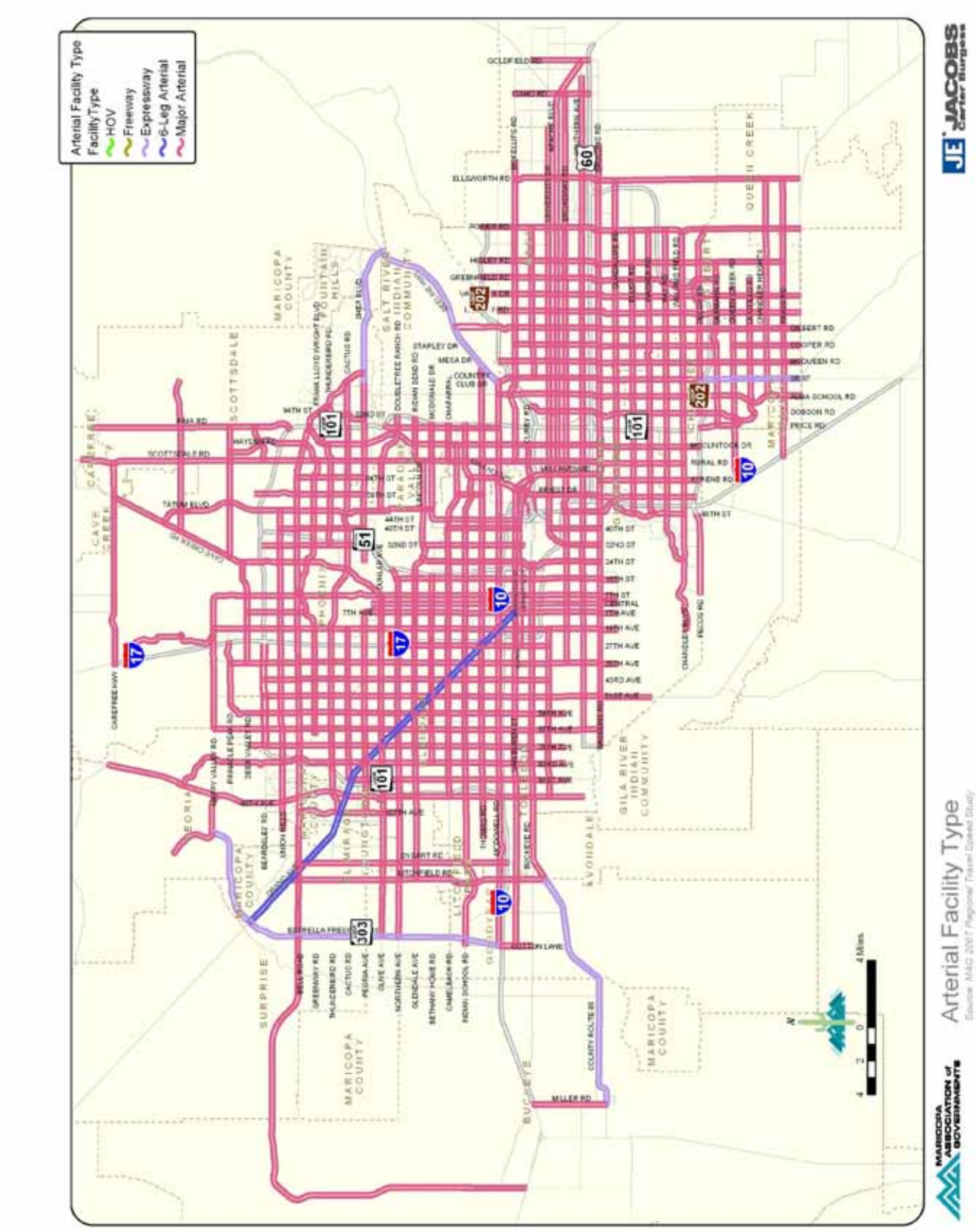


Figure 20 – Freeway Facility Type

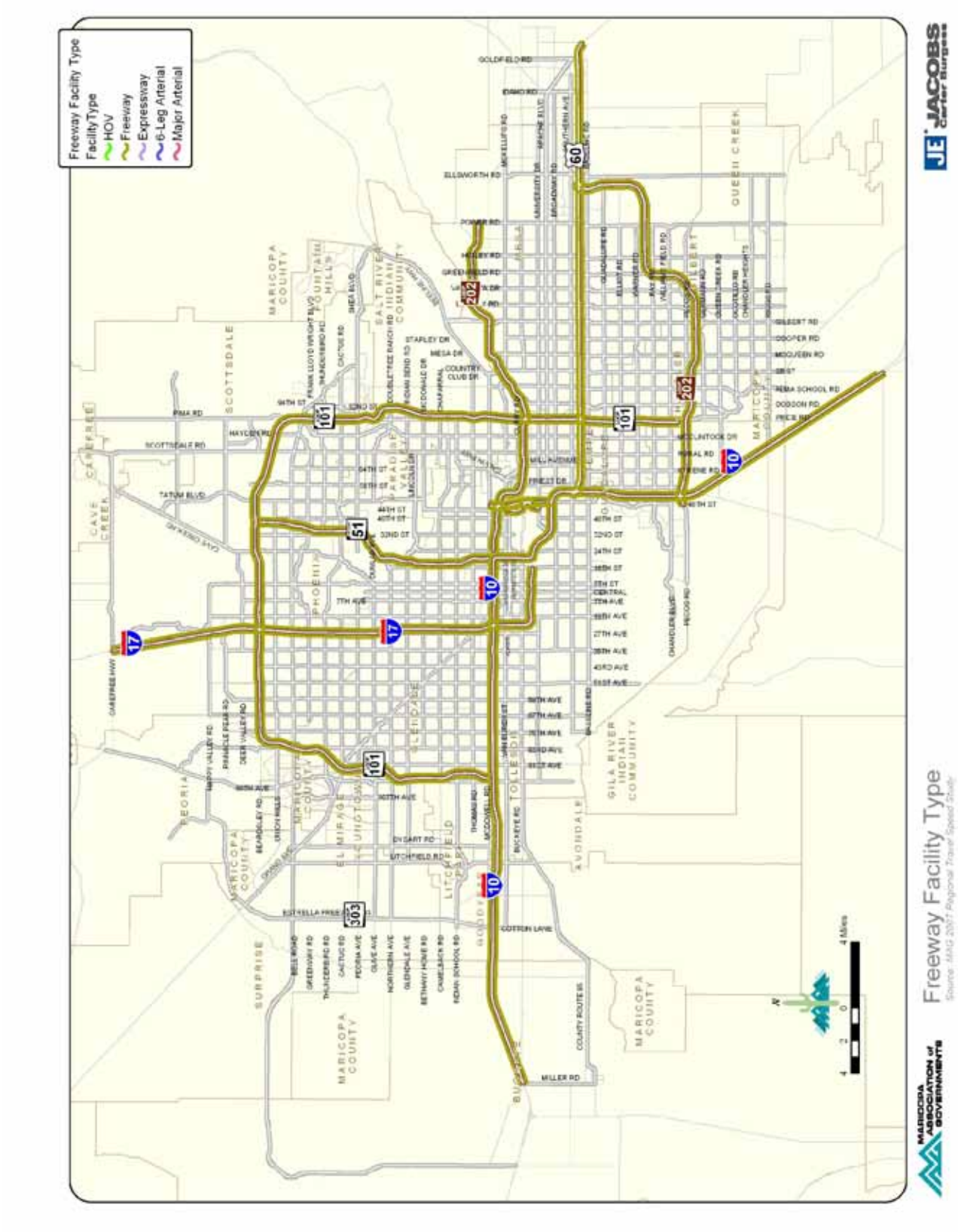
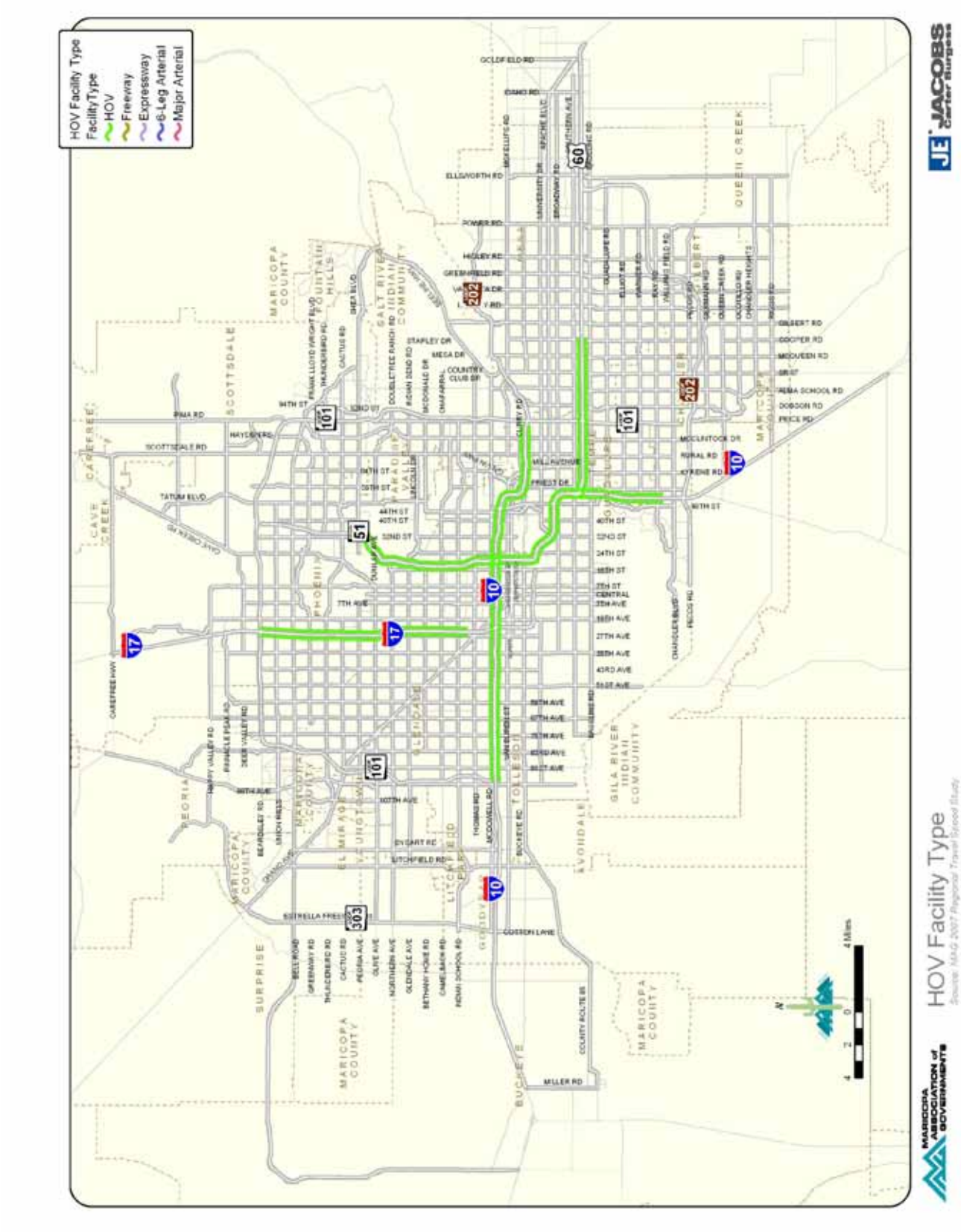


Figure 21– HOV Facility Type

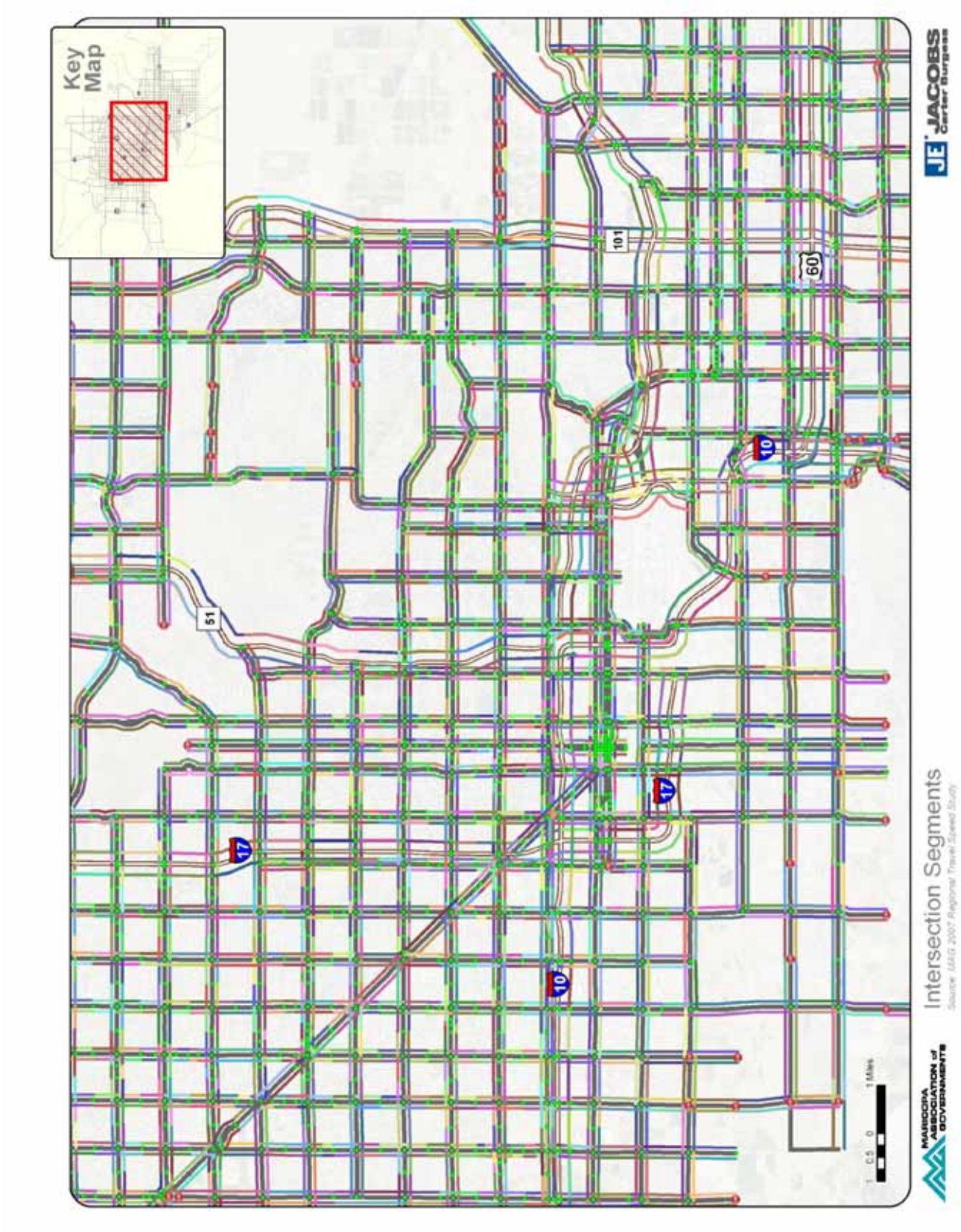


Travel time runs were conducted on 2038 centerline miles of routes along all arterials, freeways, and HOV lanes. As shown in **Figure 22**, the roadways were broken down into 7492 segments between each traffic control device and 19 runs were made on each segment, including 8 runs in each direction during the morning peak, 3 runs in each direction during the midday off peak, and 8 runs in each direction during the afternoon peak, resulting in over 71,841 miles of travel time runs. The number of runs was assigned by the MPO. Each week, technicians produced up to 223 hours of data. This data resulted in over 8.5 million data points. When the runs were completed, a statistical analysis was performed to determine the resulting confidence level and error of the data. If the confidence level was at least 85% with a 5 mph error, the runs were considered satisfactory. The 2038 centerline miles of roadway were divided among the 24 incorporated communities, towns, Indian Reservations, and Maricopa County.

3.5 Data Monitoring and Quality Control

A large part of the quality control was done automatically with computer algorithms and queries. For example, the algorithms checks that travel time runs were done in the correct time period, incorrect route ID number, instances where driver momentarily pulled off the route and got back on, and if the minimum number of required data points was met. Technicians carried a tape recorder on their travel time runs, and used them to note problem areas if encountered. While stopped, a driver would record the run number, the type of incident or problem, and the time it occurred down to the second. Examples of incidents or events that technicians would record are: construction, accidents, school zones, trains, overflowing left-turn queues, school bus stops, emergency vehicles, and signal preemption. The comments collected by the drivers are differentiated by comment type. For example, those times when the drivers encountered an active school zone, that was noted for the applicable speed limit. If the observation was determined to be non-recurring, the data for the segment was flagged so that it was not included in the calculation of averages. Furthermore, non-recurring data points, such as accidents, were removed if they were more than four standard deviations from the average combined speeds for the time periods surveyed (AM, MD, and PM).

Figure 22 – Intersection Segments



Once the data had gone through the quality control process, it was uploaded to the project website so that team members and MAG staff could view the data. Data was transferred and reviewed weekly, so the website was also updated on a weekly basis. The information on the website included everything completed to date and could be viewed but not edited. Only the project manager could edit the data on the website. The data collection supervisor would review the information, and from that, prepare a schedule for technicians for the next week. This ensured that no runs were repeated unnecessarily.

3.6 Data Analysis

The data analysis includes various levels of review, automated Quality Assurance/Quality Control (QA/QC), and manual QA/QC. Many of the primary steps taken to process the large amounts of data are shown below.

- Assign segments for aggregation purposes
  - Inntersection segment
  - Speed limit
  - School zone speed (if applicable)
  - Number of lanes
  - Area Type/Facility Type
  - Jurisdiction
- Calculate average Space Mean Speed and Time Mean Speed.
- Calculate the queue measure as the first point in the segment where the speed <= 3 MPH and extends to the first intersection.
- Calculate the stop delay as the count of one second GPS points where the speed <=3 MPH
- Calculate the segment delay as the difference between travel time and free flow travel time.
- Reference: LOS based on delay and speed parameters
- Calculate travel time
- Calculate free flow travel time
- Average travel time by intersection segment

3.7 Additional Illustrations of Performance

Tables 3-5 summarize the resulting speed error at an 85% confidence interval for each of the time periods. They are further broken down by Area Type, Facility Type and Number of Lanes. As expected, the resulting error is greatest for the 6-leg arterial types due to the large variation in performance along Grand Ave.

Table 3 – AM Speed Error at 85% Confidence Level

Area Type	Lanes	Functional Classification						
		HOV	Freeway	Expressway	Collector	6 Leg Arterial	Major Arterial	ALL
CBD	All	2.4	3.0	5.2	-	5.1	4.0	3.7
CBD (Outlying)	All	3.4	3.4	3.4	6.5	-	4.0	3.9
Mixed Urban	All	4.2	3.0	5.0	3.6	-	3.8	3.7
Suburban	All	-	3.2	3.9	3.0	-	4.4	4.1
Rural	1	-	-	4.7	2.9	-	4.1	4.0
	2 or more	-	3.3	3.7	2.1	-	4.0	3.6
ALL		3.5	3.2	4.0	4.2	5.1	4.0	3.9

Table 4 –MD Speed Error at 85% Confidence Level

Area Type	Lanes	Functional Classification						
		HOV	Freeway	Expressway	Collector	6 Leg Arterial	Major Arterial	ALL
CBD	All	-	6.1	10.3	-	10.6	8.2	8.0
CBD (Outlying)	All	-	6.6	6.0	6.5	-	6.7	6.7
Mixed Urban	All	-	4.1	9.1	5.3	-	6.8	6.5
Suburban	All	-	3.5	6.5	4.4	-	6.5	6.0
Rural	1	-	-	5.3	3.0	-	5.2	5.1
	2 or more	-	4.3	3.8	3.4	-	6.2	5.2
ALL		-	4.6	6.0	5.1	10.6	6.6	6.3

Table 5 –PM Speed Error at 85% Confidence Level

Area Type	Lanes	Functional Classification						
		HOV	Freeway	Expressway	Collector	6 Leg Arterial	Major Arterial	ALL
CBD	All	3.6	5.7	5.5	-	4.8	4.1	4.5
CBD (Outlying)	All	3.1	4.3	3.8	2.9	-	4.1	4.0
Mixed Urban	All	2.9	2.9	7.7	2.4	-	3.9	3.7
Suburban	All	-	3.3	4.3	3.6	-	4.3	4.1
Rural	1	-	-	3.9	1.7	-	3.5	3.3
	2 or more	-	3.8	3.3	1.5	-	3.6	3.7
ALL		3.1	3.5	4.3	2.8	4.8	4.0	3.9

3.8 Data Aggregation

The summary data has been aggregated on various levels. Data can be viewed from levels as detailed as the raw 1-second point data to the intersection segments. This allows the data to be presented in various forms depending on the audience. **Figure 24** illustrates the segmentation of the data for the Intersection Segments.

3.9 Problems in Data Collection

In a project as large as this travel time study, data collection challenges are expected. Light Rail construction was an issue in several locations. Travel time runs could not be conducted on roadways that were under construction because the data would not be meaningful to the project. Technicians noted areas of construction during the mapping process. If construction was completed, travel time runs were conducted on those roadways as they became available. Otherwise, they are noted as being under construction and travel time runs were delayed if at all possible.

4.0 2007 Speeds and Travel Times

There was an enormous amount of data collected for the 2007 Regional Travel Time & Travel Speed Study. The easiest way to present and assimilate the information is in tables, charts, and graphs. This section presents the results of the study in visual format, allowing the reader to reach individual judgments at their discretion, and offering summary conclusions only, by section.

The following sections display the relationship between speeds and functional class for the 2038 centerline miles of roadway included in the study. This section displays all information collected for this study for evaluation, interpretation, and use in developing and prioritizing future projects.

4.1 Travel Speeds by Jurisdiction

Table 6 summarizes the results by jurisdiction and facility type, while **Table 7** tabulates the results for all facility types by jurisdiction. Tables 4 and 5 provide summaries of the travel time runs including:

- Functional class and jurisdiction
- Travel Speed – average speed for all routes
- Speed Limit – weighted average speed limits for each run performed, may vary by time period depending on the number of runs on various routes
- Percent Posted Speed Limit – represents the ratio of Travel Speed to Speed Limit
- Running Speed – Average speed for travel times > 3 mph
- Stop Delay – average amount of time spent < 3 mph per mile
- Segment Delay – Delay encountered over all segments less than the theoretical time to traverse the segments.

Table 6 – Jurisdictional Breakdown

Jurisdiction	Functional Classification					
	HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
Apache Junction	-	8	-	-	35	43
Avondale	-	8	-	-	33	41
Buckeye	-	16	2	-	0	18
Carefree	-	-	-	-	3	3
Cave Creek	-	-	-	-	3	3
Chandler	1	30	10	-	225	265
El Mirage	-	-	-	4	12	16
Fountain Hills	-	-	8	-	-	8
Gilbert	-	16	-	-	216	232
Glendale	-	15	-	10	203	227
Goodyear	-	14	8	-	36	58
Guadalupe	3	3	-	-	4	9
Litchfield Park	-	-	-	-	3	3
Maricopa County	6	55	72	15	417	565
Mesa	9	65	-	-	337	411
Paradise Valley	-	-	-	-	30	30
Peoria	-	13	-	7	109	130
Phoenix	90	179	-	11	1161	1440
Pinal County	-	16	-	-	-	16
Queen Creek	-	-	-	-	4	4
Scottsdale	-	15	9	-	248	272
Surprise	-	-	14	2	31	47
Tempe	26	41	-	-	153	220
Tolleson	-	-	-	-	12	12
TOTAL	134	492		49	3275	4074

Table 7 – Travel Speed, % Posted Speed, Running Speed, and Delay

Jurisdiction	Travel Speed (MPH)	Speed Limit (MPH)	% Posted Speed	Running Speed (MPH)	Stop Delay (sec/mile)	Segment Delay (sec/mile)
Apache Junction	41.3	45.0	91.7%	43.3	10.2	18.0
Avondale	44.6	49.3	90.4%	46.7	12.0	24.7
Buckeye	70.6	72.1	97.9%	70.6	0.6	3.4
Carefree	35.1	30.1	116.4%	35.4	1.1	0.3
Cave Creek	36.6	46.7	78.4%	40.8	42.2	61.5
Chandler	40.8	48.1	84.9%	44.1	17.5	30.2
El Mirage	32.5	43.0	75.5%	37.4	31.8	51.6
Fountain Hills	40.9	51.5	79.4%	44.4	16.1	30.4
Gilbert	40.0	47.5	84.2%	43.5	17.6	29.5
Glendale	37.4	42.6	87.8%	40.3	21.1	33.0
Goodyear	46.2	55.9	82.5%	48.0	10.4	26.3
Guadalupe	41.9	53.1	79.0%	42.8	8.8	43.3
Litchfield Park	38.4	40.0	96.0%	42.1	13.0	14.7
Maricopa County	45.2	49.7	90.9%	47.3	10.7	22.2
Mesa	43.7	49.1	89.0%	45.4	12.6	24.8
Paradise Valley	33.0	36.7	89.7%	35.3	13.7	21.7
Peoria	40.5	42.9	94.4%	43.0	17.6	25.9
Phoenix	38.6	45.3	85.2%	41.0	19.9	37.0
Queen Creek	30.9	36.4	84.9%	33.6	10.6	19.7
Scottsdale	37.7	45.1	83.5%	40.9	23.0	37.2
Surprise	38.5	44.4	86.8%	41.6	19.3	32.6
Tempe	40.6	50.5	80.2%	42.5	20.5	45.4
Tolleson	30.1	37.8	79.6%	33.2	28.5	45.7

Figures 23-36 summarize the data for each of the time periods. **Table 6** includes the summaries of the average speed by jurisdiction. **Tables 9-11** include the results summarized by area type and roadway facility type (i.e. functional classification).

Figure 23 - Average Freeway Speed - AM

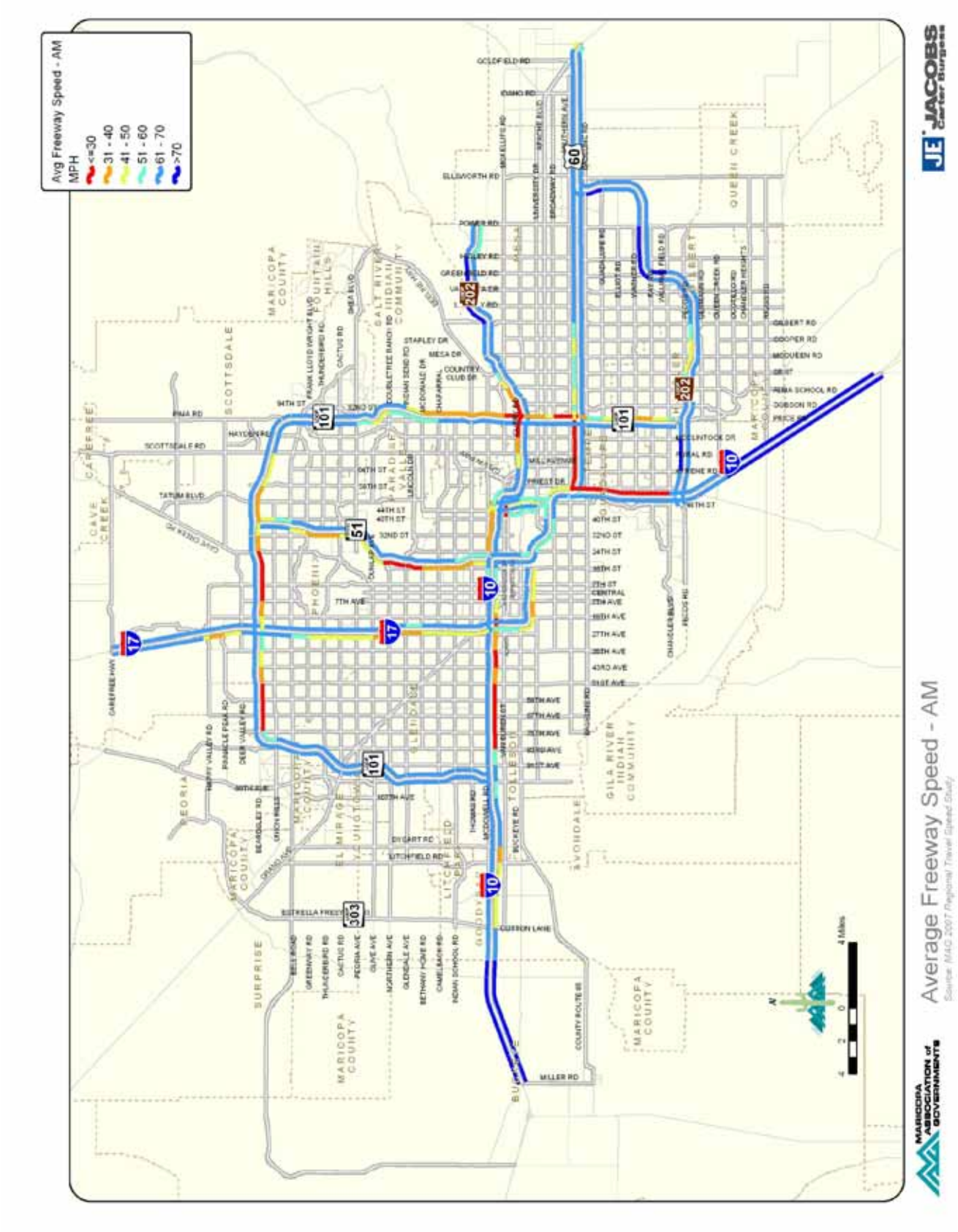


Figure 24 - Average Freeway Speed - Mid-Day

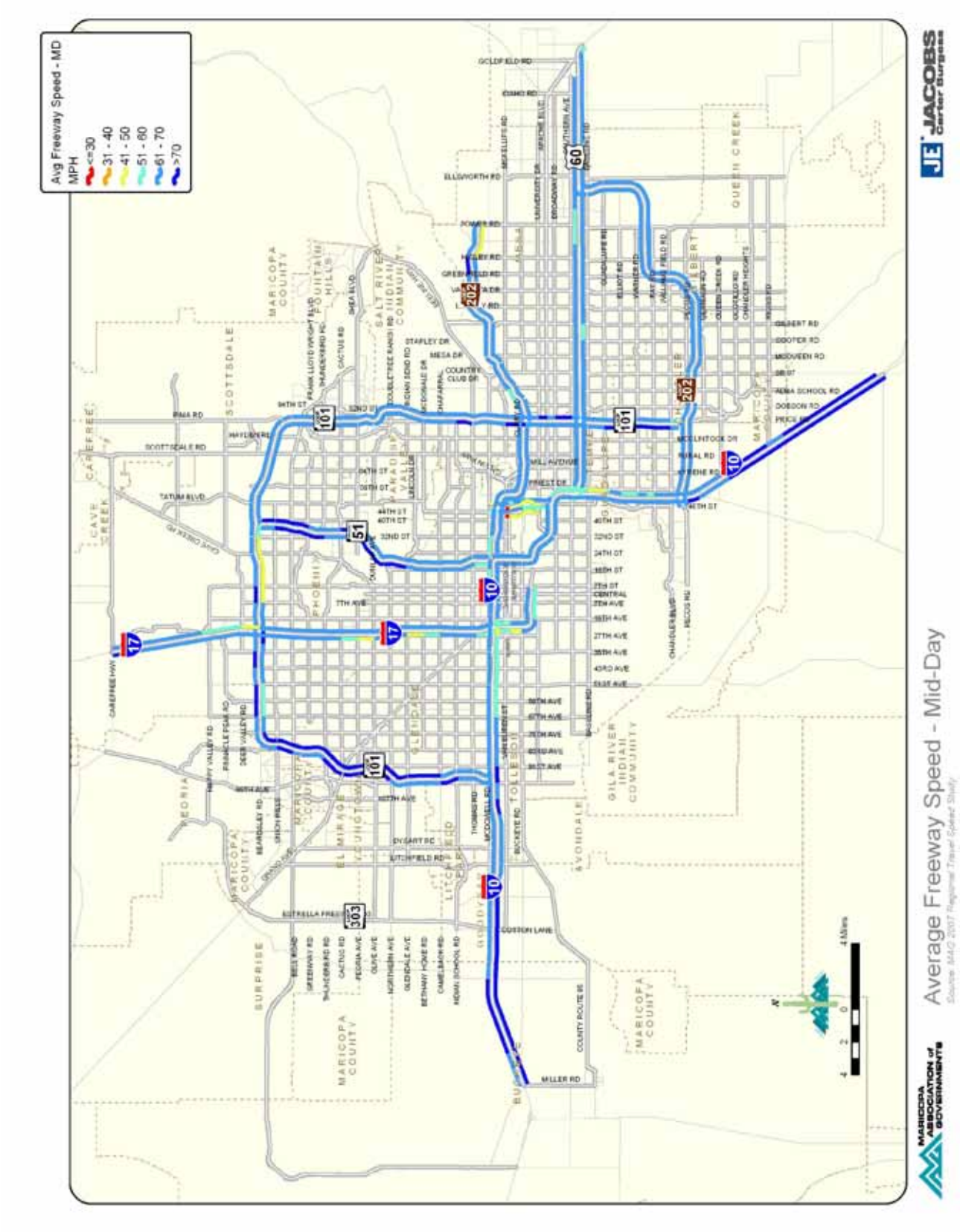


Figure 25 – Average Freeway Speed – PM

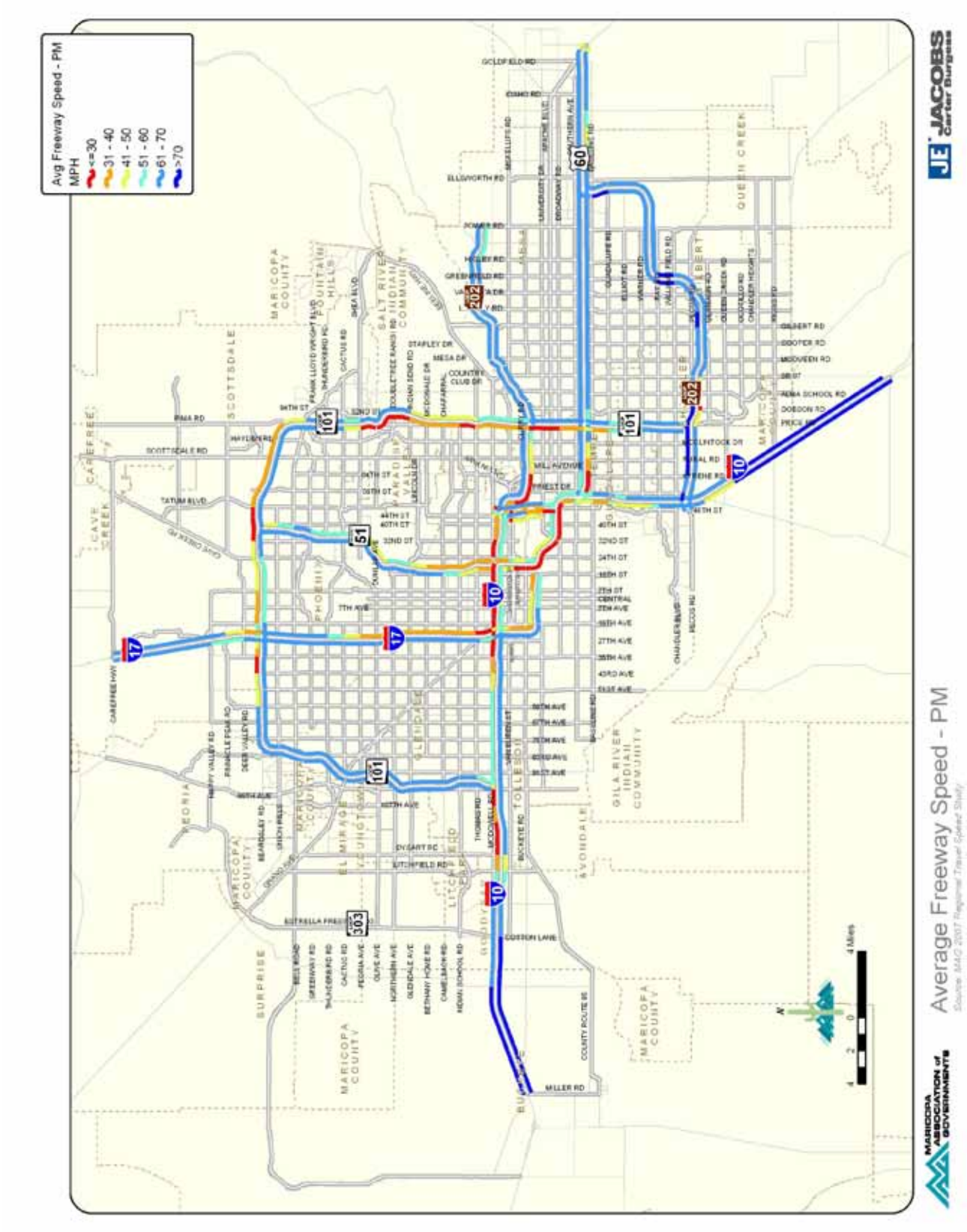


Figure 26 - Average HOV Speed - AM

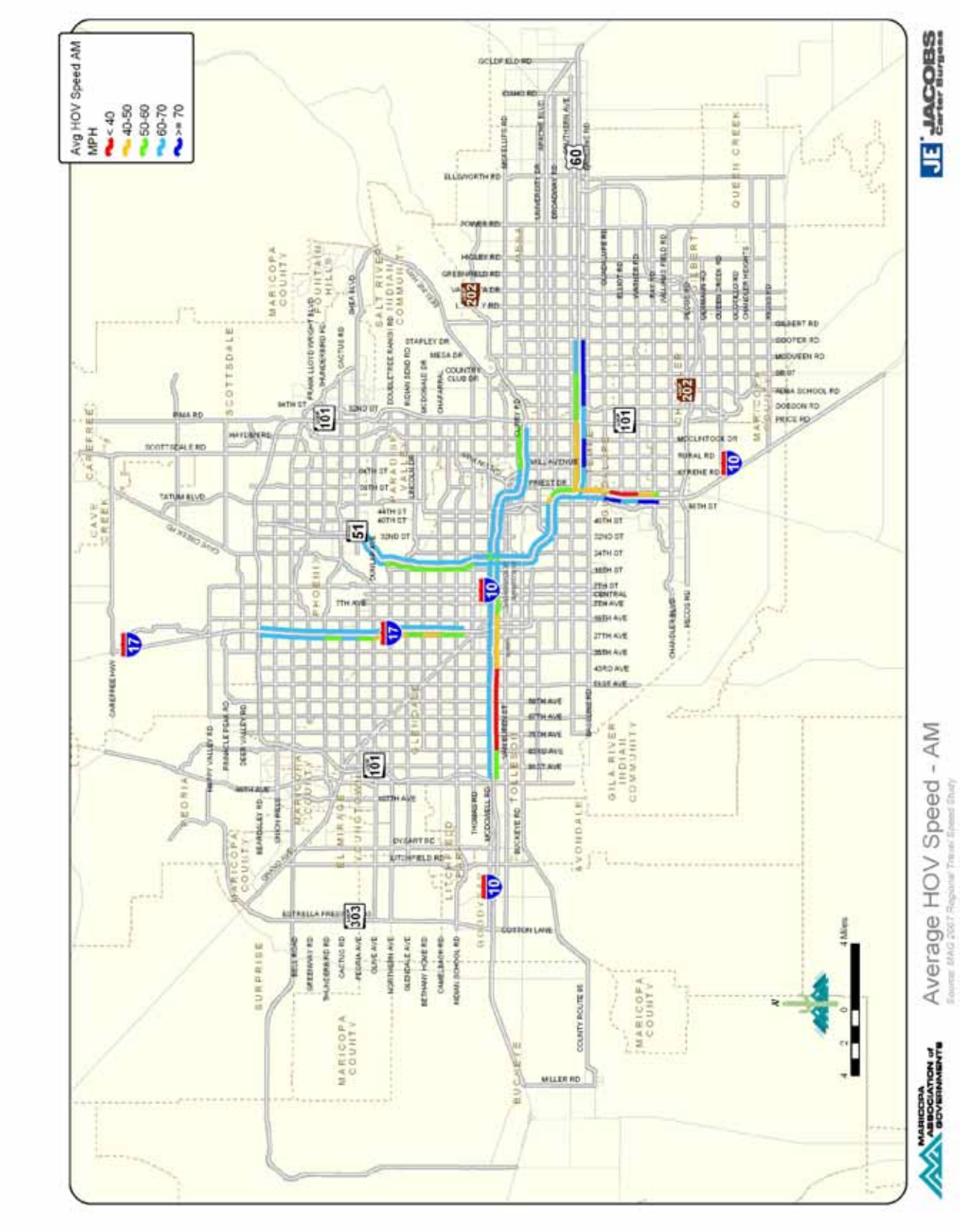


Figure 27 - Average HOV Speed - PM

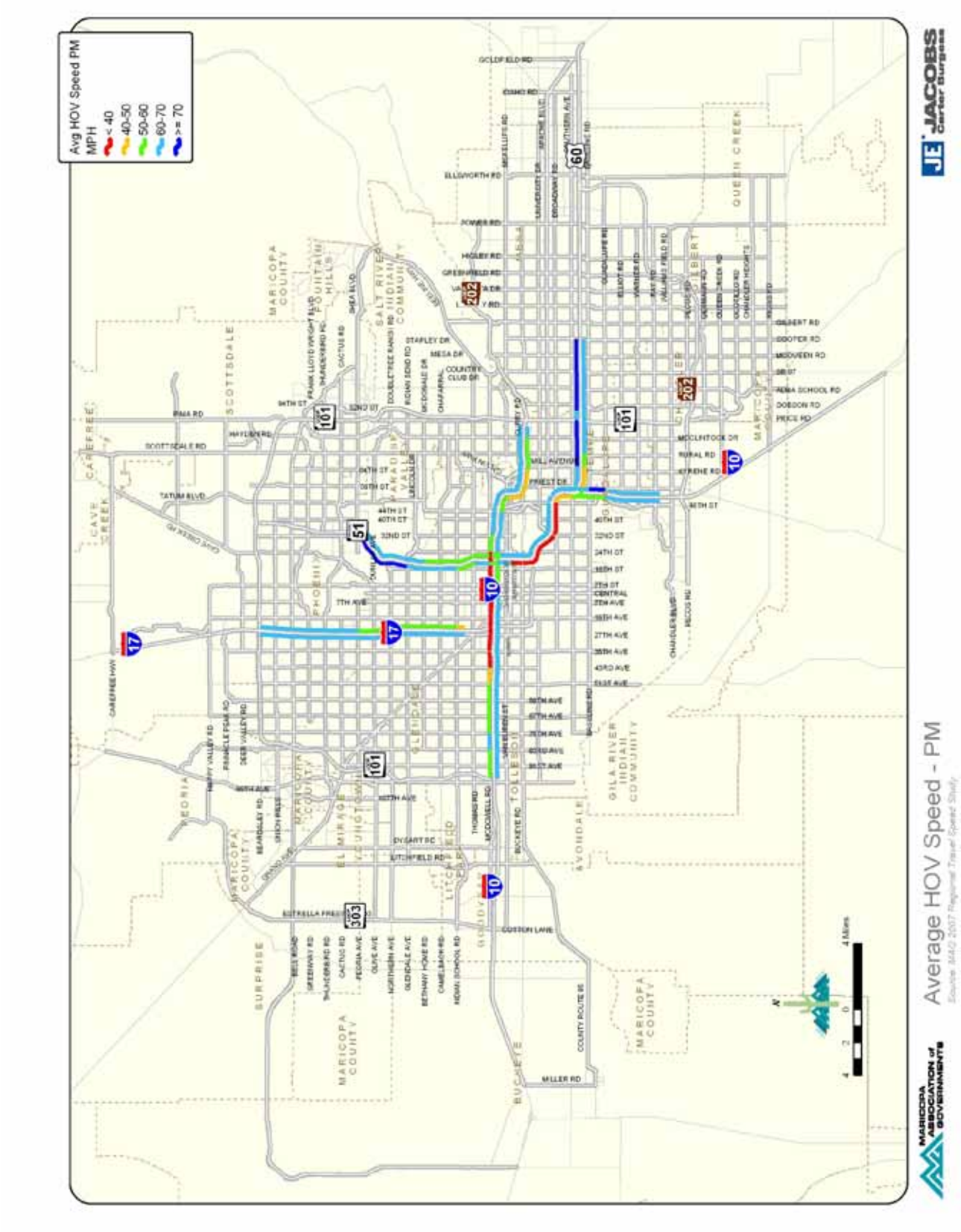


Figure 28 - Average Arterial Speed - AM

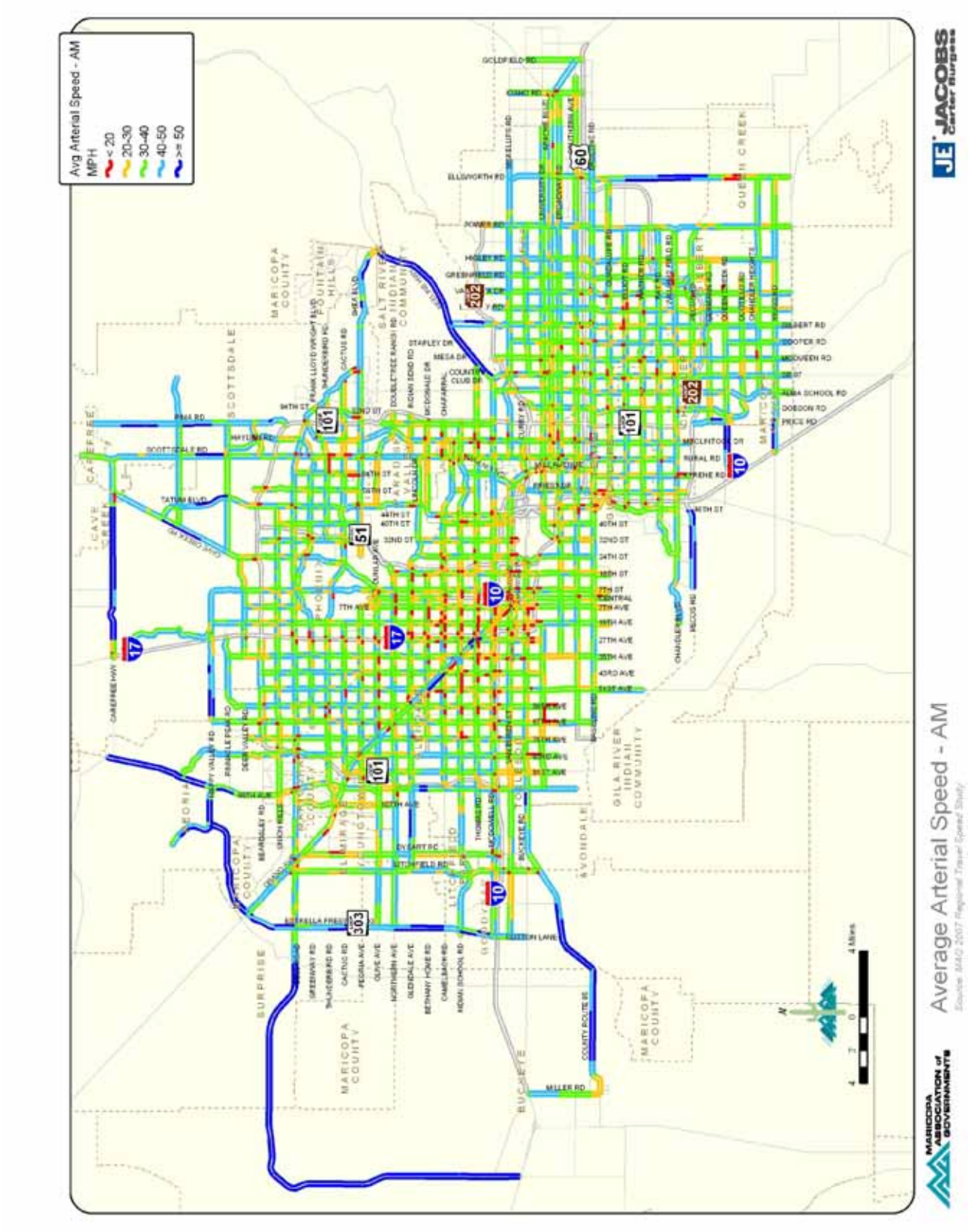


Figure 29 – Average Arterial Speed - Mid-Day

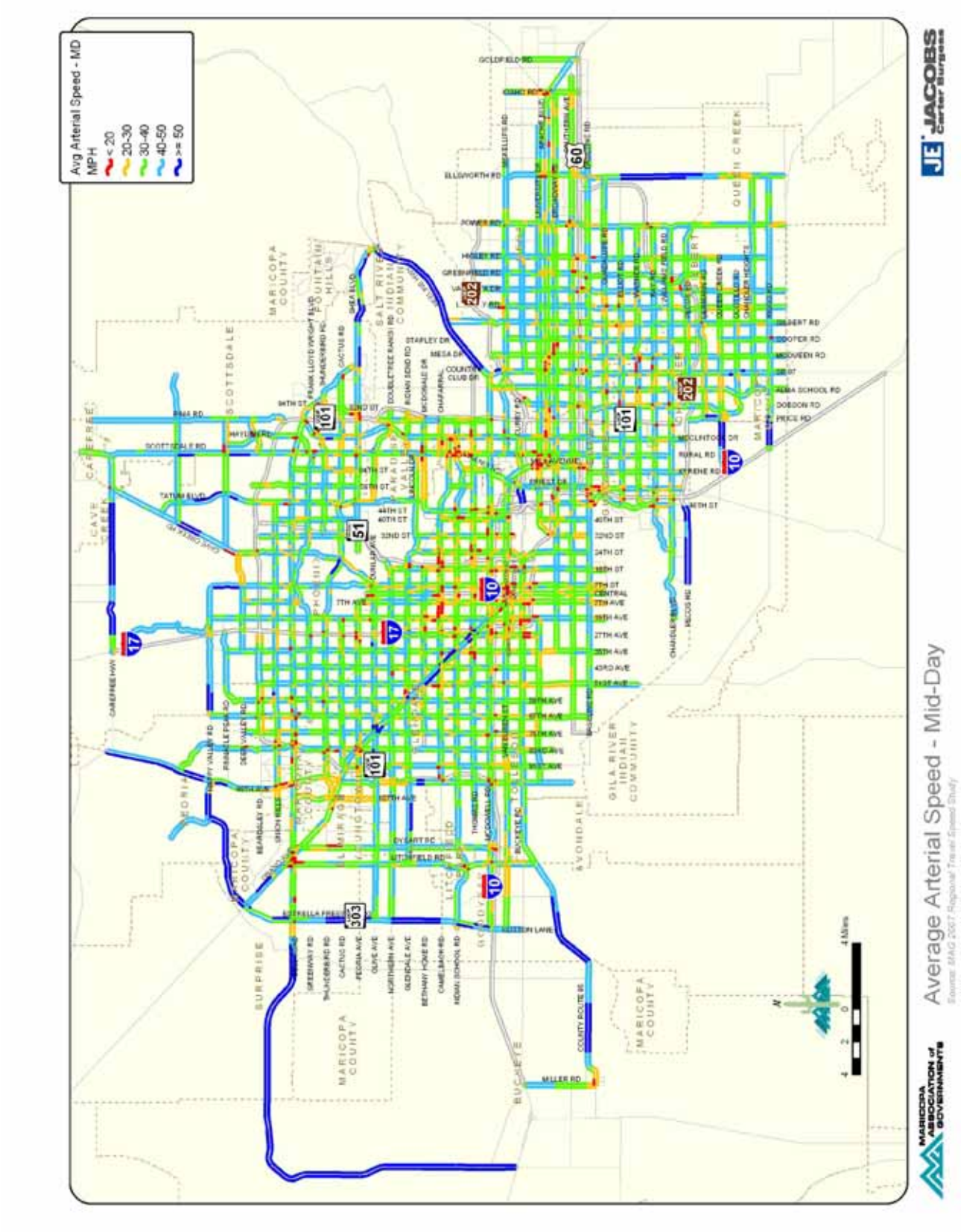


Figure 30 - Average Arterial Speed - PM

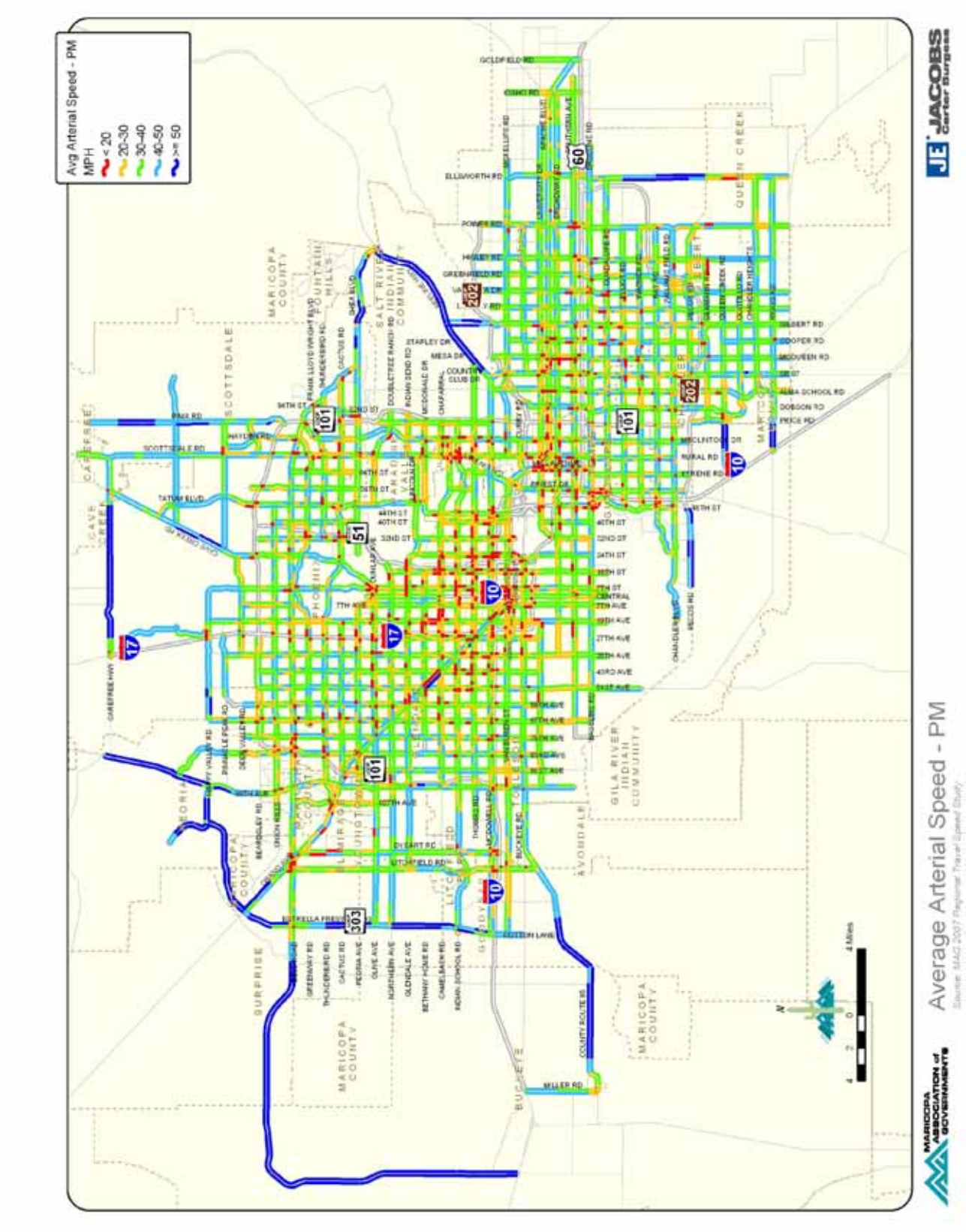


Figure 31- Percent of Posted Speed Freeway - AM

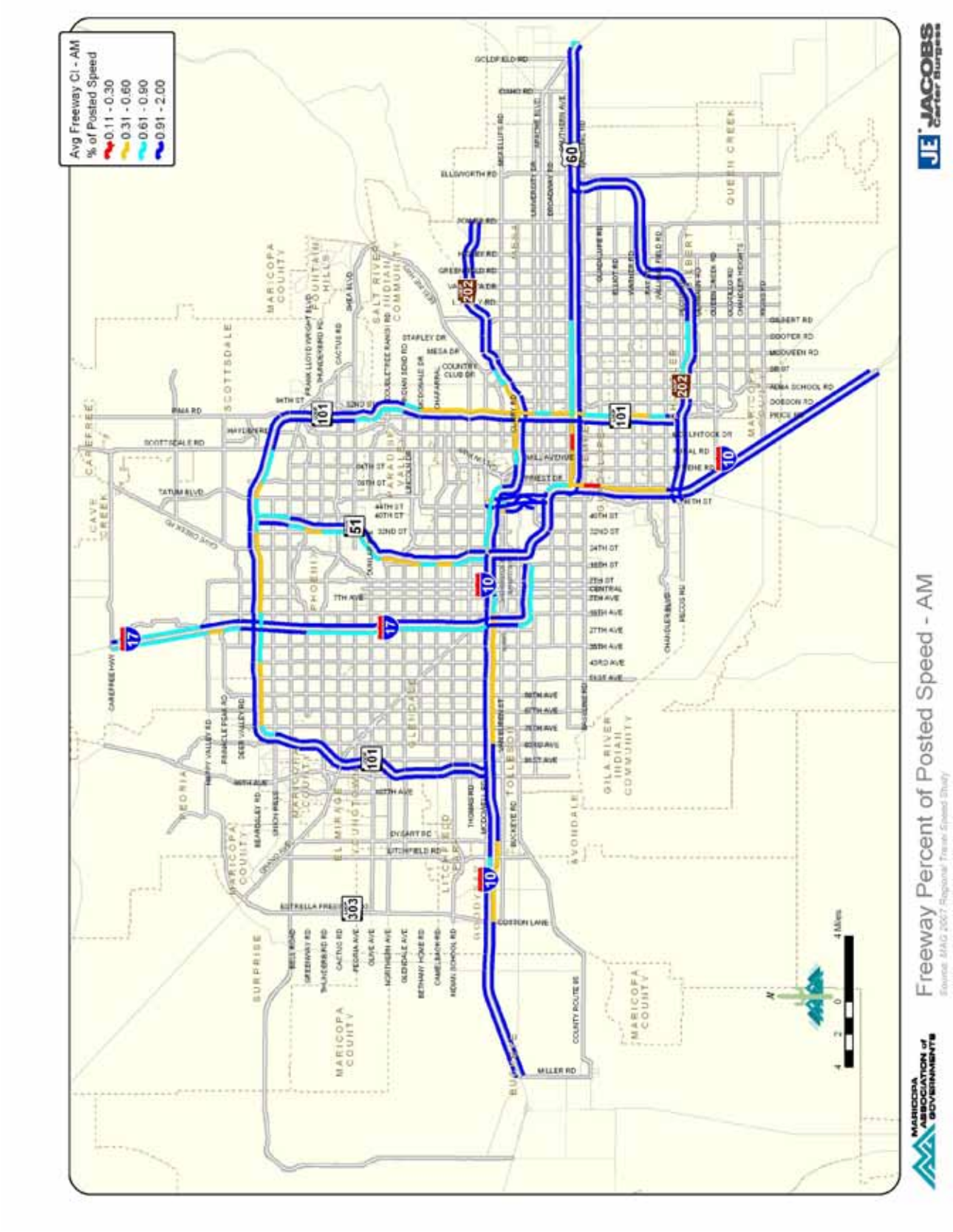


Figure 32 –Percent of Posted Speed Freeway – Mid-Day

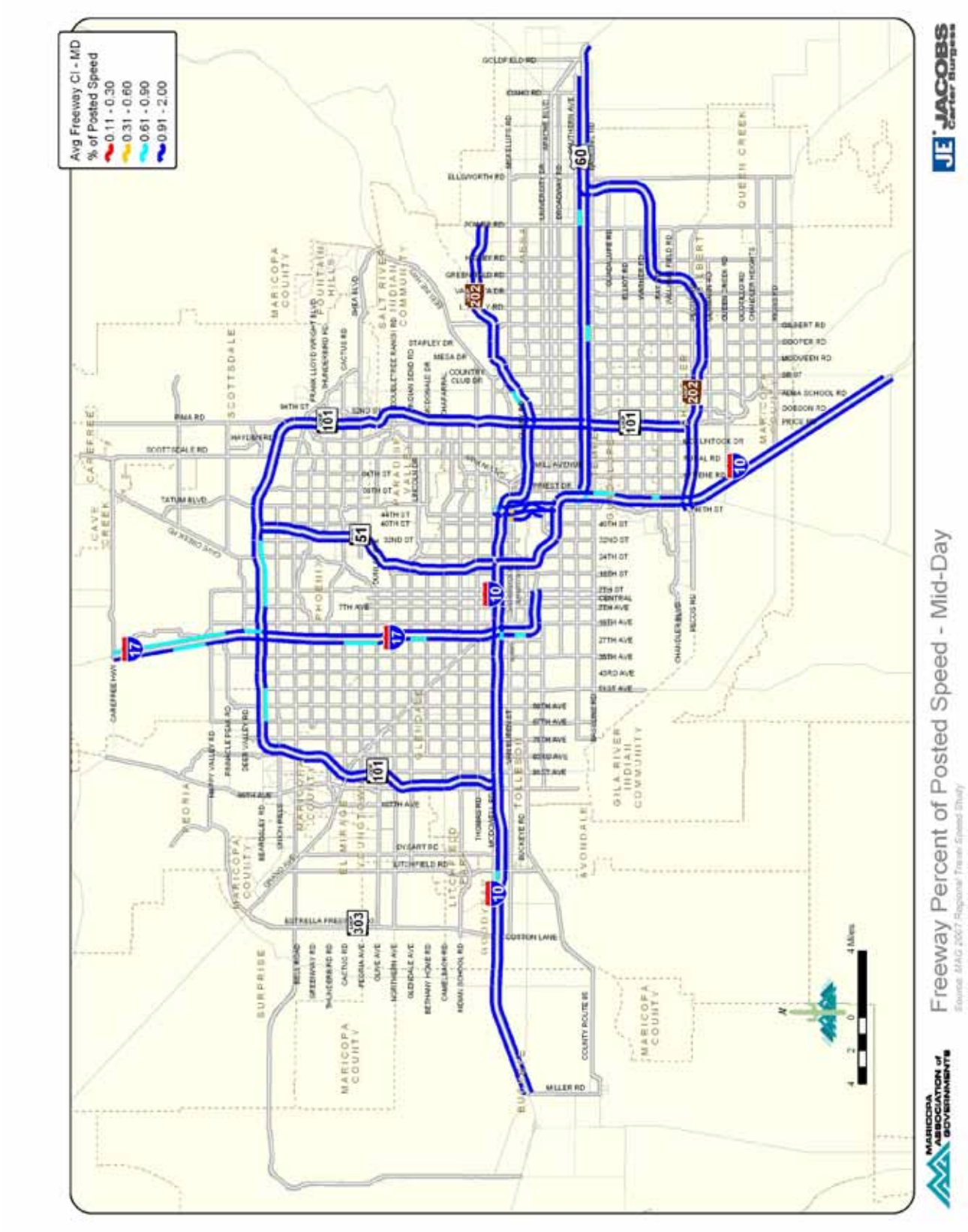


Figure 33 - Percent of Posted Speed Freeway - PM

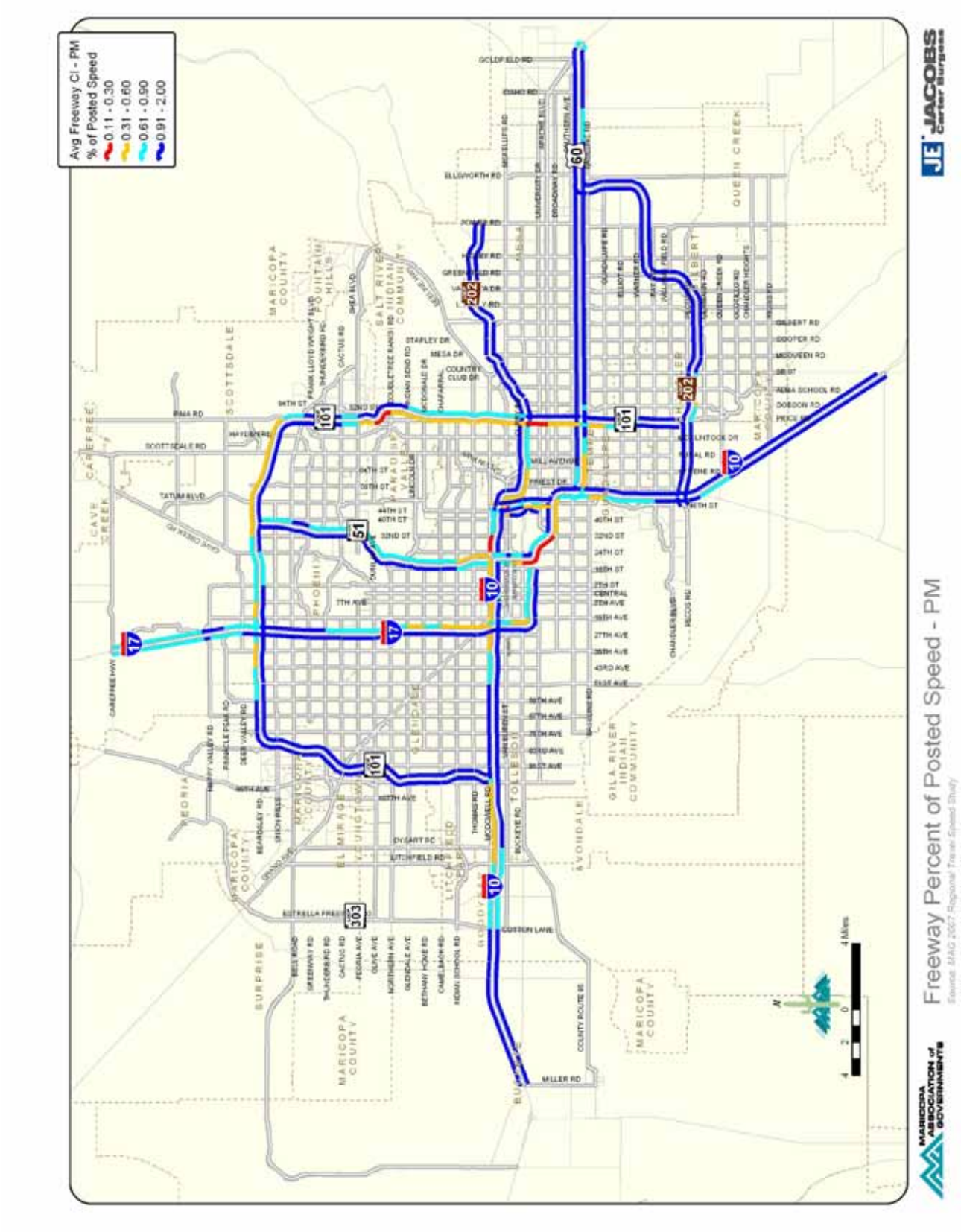


Figure 34 - Percent of Posted Speed Arterial - AM

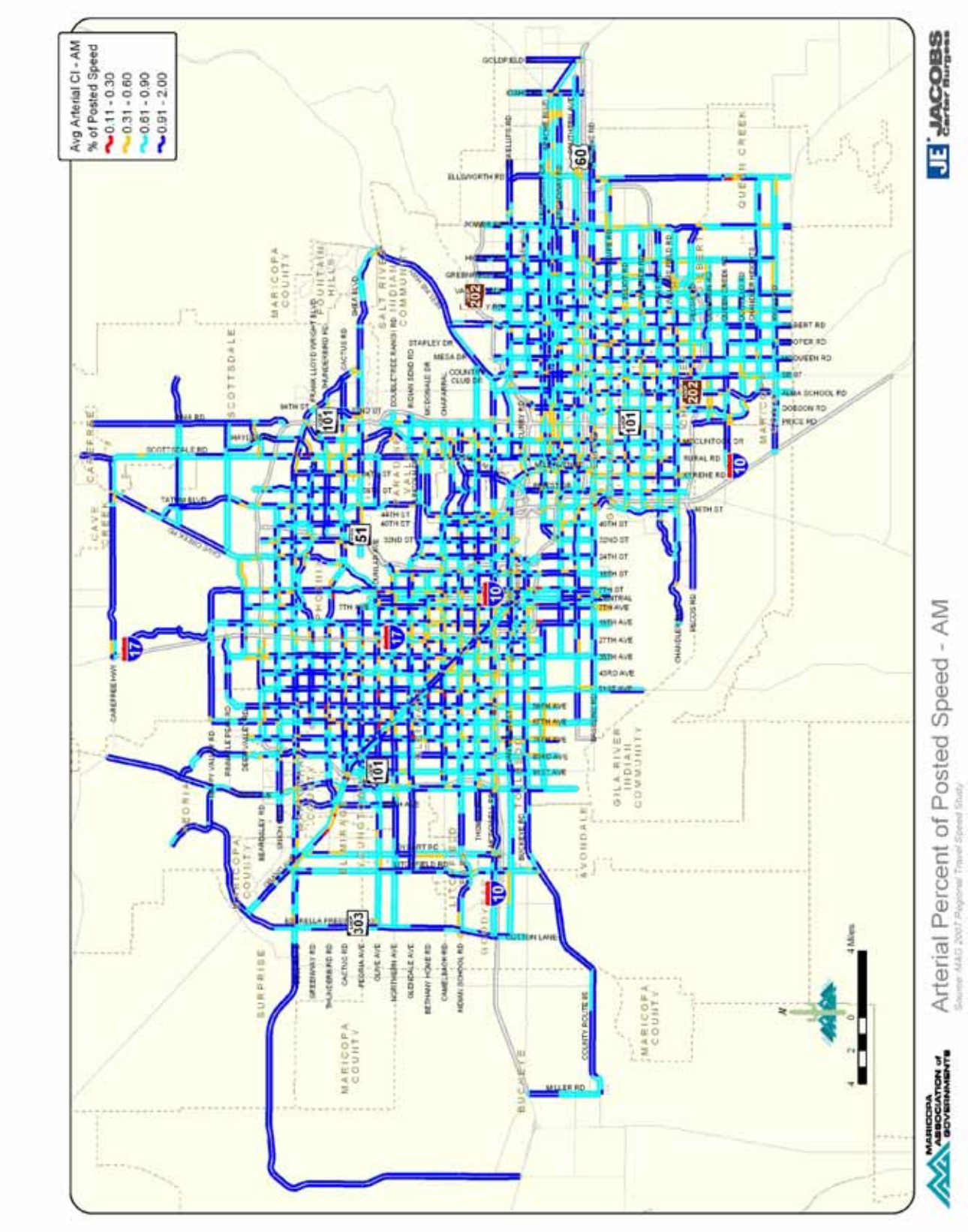


Figure 35 – Percent of Posted Speed Arterial– Mid-Day

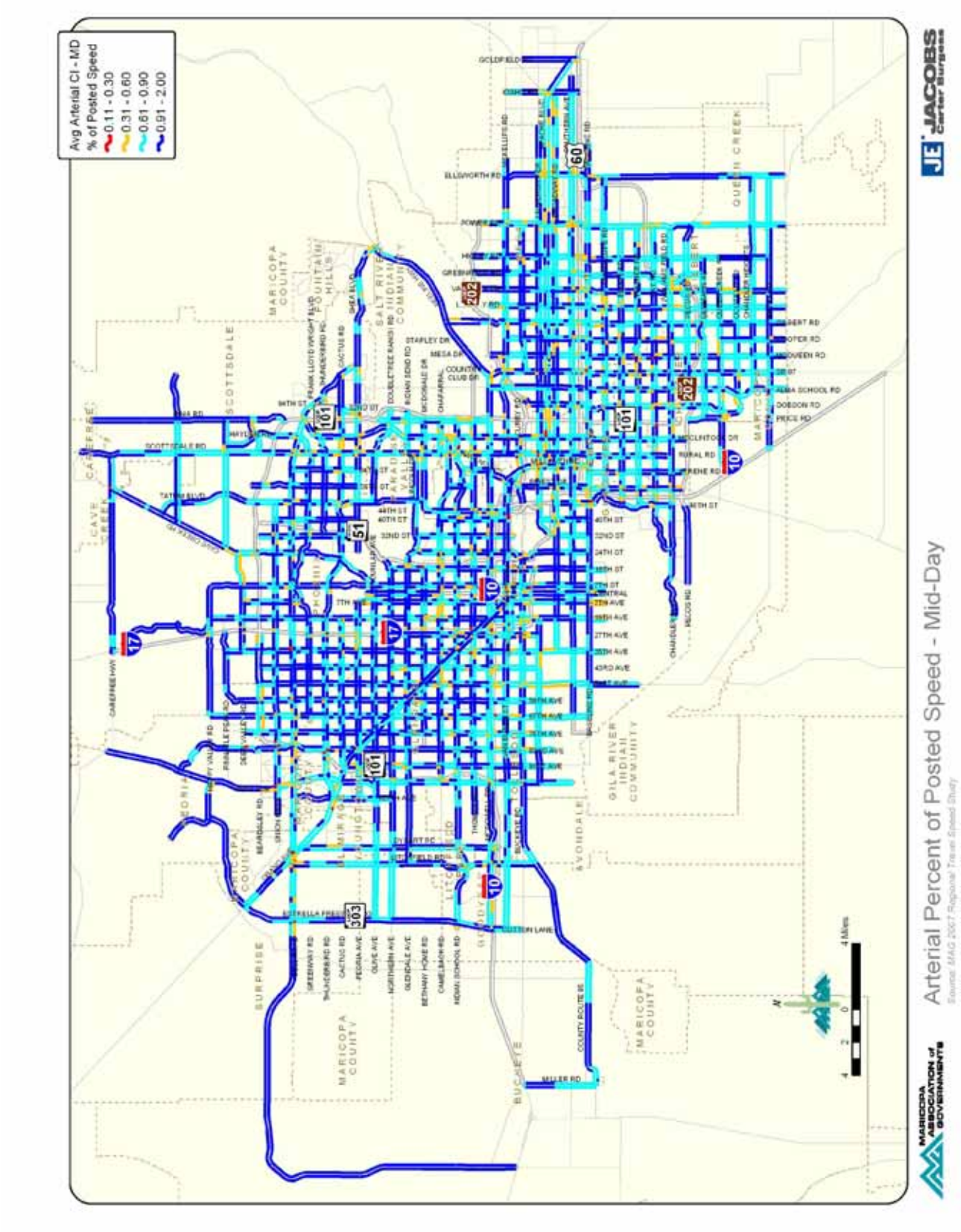


Figure 36 - Percent of Posted Speed Arterial - PM

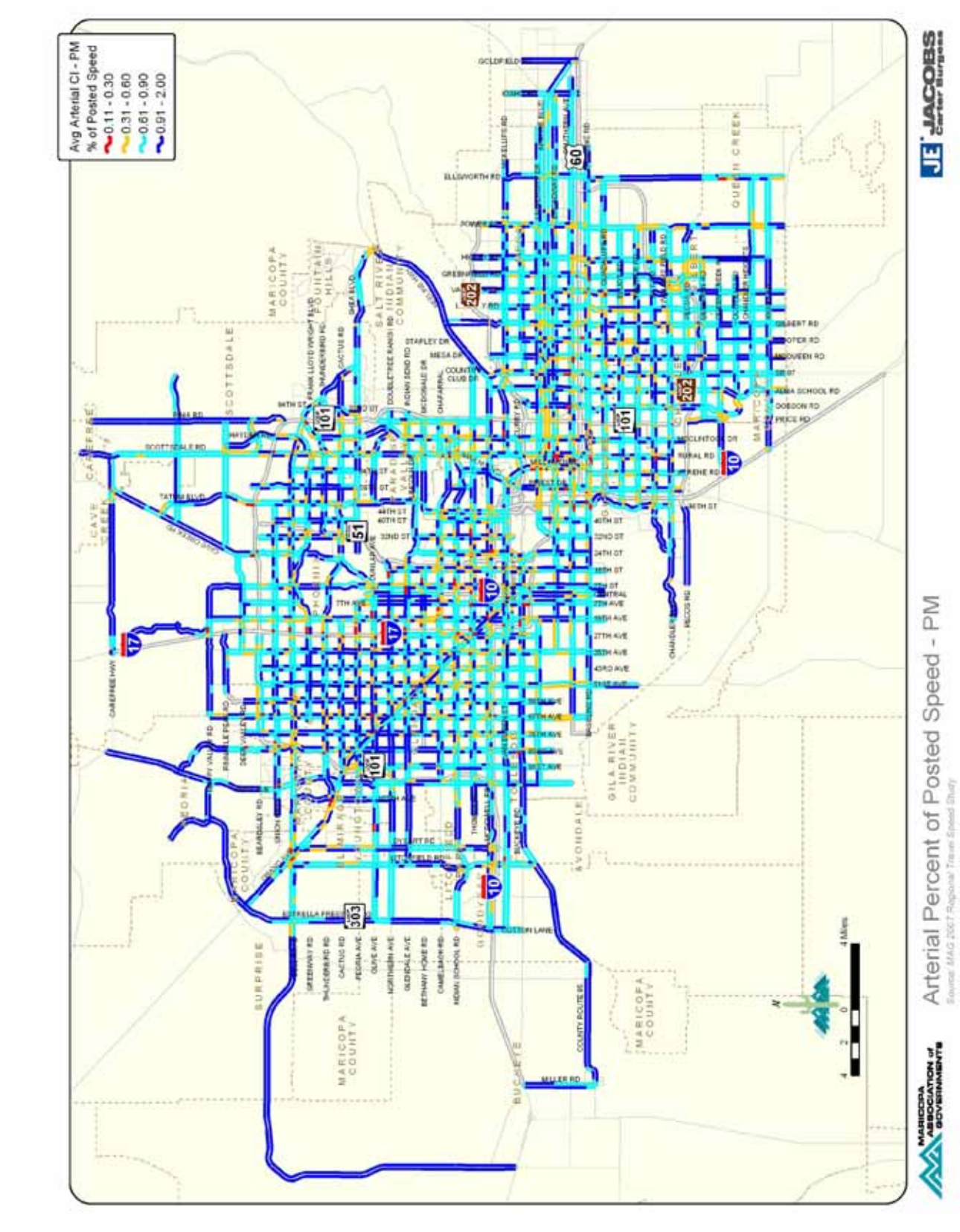


Table 8 – AM, MD and PM Weighted Average Speeds

Jurisdiction	Arterial					Freeway				
				Change in Avg Speed					Change in Avg Speed	
	AM	MD	PM	AM-MD	MD-PM	AM	MD	PM	AM-MD	MD-PM
Apache Junction	33.8	33.4	33.9	-0.4	0.5	65.2	64.1	65.7	-1.1	1.5
Avondale	37.5	37.9	34.3	0.4	-3.5	64.6	68.4	49.3	3.8	-19.2
Buckeye	26.7	25.6	29.0	-1.1	3.4	73.9	71.4	74.4	-2.5	3.0
Carefree	34.8	35.5	34.9	0.7	-0.6	0.0	0.0	0.0	0.0	0.0
Cave Creek	35.3	40.6	35.5	5.3	-5.1	0.0	0.0	0.0	0.0	0.0
Chandler	35.1	36.8	34.7	1.7	-2.1	60.1	67.8	65.2	7.6	-2.6
El Mirage	30.8	35.4	32.1	4.5	-3.3	0.0	0.0	0.0	0.0	0.0
Fountain Hills	41.6	40.5	40.5	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
Gilbert	35.4	38.1	34.8	2.6	-3.3	69.4	67.7	69.5	-1.8	1.9
Glendale	35.3	37.5	34.1	2.2	-3.5	57.4	68.6	64.2	11.2	-4.4
Goodyear	37.4	38.3	36.2	0.9	-2.1	56.3	68.4	60.2	12.1	-8.2
Guadalupe	22.7	22.9	21.5	0.2	-1.4	46.4	55.9	55.7	9.5	-0.2
Litchfield Park	37.0	39.6	38.9	2.7	-0.8	0.0	0.0	0.0	0.0	0.0
Maricopa County	41.6	42.4	41.4	0.9	-1.0	60.2	67.1	57.5	6.9	-9.6
Mesa	36.6	37.5	34.7	0.9	-2.8	64.3	64.6	66.4	0.3	1.8
Paradise Valley	33.0	34.3	32.4	1.3	-1.9	0.0	0.0	0.0	0.0	0.0
Peoria	36.4	38.6	36.1	2.1	-2.5	66.4	71.1	66.1	4.7	-5.0
Phoenix	33.8	36.4	32.5	2.7	-3.9	56.5	63.5	53.0	7.0	-10.5
Pinal County	0.0	0.0	0.0	0.0	0.0	71.6	70.0	70.6	-1.6	0.6
Queen Creek	29.3	31.3	31.9	2.0	0.6	0.0	0.0	0.0	0.0	0.0
Scottsdale	36.0	36.6	34.3	0.6	-2.4	64.5	67.2	53.5	2.7	-13.7
Surprise	40.2	37.6	37.3	-2.5	-0.3	0.0	0.0	0.0	0.0	0.0
Tempe	32.8	34.9	30.8	2.1	-4.1	52.8	64.3	53.7	11.5	-10.6
Tolleson	30.8	31.1	28.8	0.4	-2.3	0.0	0.0	0.0	0.0	0.0
All	35.5	37.6	34.4	2.1	-3.1	59.5	65.8	58.4	6.4	-7.4

Table 9 – AM Weighted Average Speed by Area Type, Facility Type, and Lanes

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	60.4	55.6	-	29.8	28.5	38.0
CBD (Outlying)	All	60.2	52.9	-	39.2	32.7	38.4
Mixed Urban	All	61.3	59.6	39.3	36.4	34.9	40.0
Suburban	All	-	62.6	49.1	35.7	36.8	42.1
Rural	1	-	-	52.5	-	37.6	38.6
	2 or more	-	63.4	56.0	-	48.4	56.6
ALL		60.5	59.2	49.5	36.3	35.1	40.9

Table 10 – Midday Weighted Average Speed by Area Type, Facility Type, and Lanes

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	-	62.1	-	33.2	29.4	36.0
CBD (Outlying)	All	-	62.4	-	43.9	34.9	39.2
Mixed Urban	All	-	67.0	42.5	39.7	36.4	40.6
Suburban	All	-	66.1	49.7	36.7	38.2	42.6
Rural	1	-	-	50.2	-	40.0	40.8
	2 or more	-	68.8	55.1	-	49.6	57.3
ALL		-	65.8	50.5	39.2	37.1	41.9

Table 11 – PM Weighted Average Speed by Area Type, Facility Type, and Lanes

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	45.4	41.8	-	29.9	24.7	30.9
CBD (Outlying)	All	59.1	50.8	-	38.2	30.6	36.6
Mixed Urban	All	65.5	60.9	38.3	35.7	33.6	39.8
Suburban	All	-	61.4	50.9	33.5	36.4	41.4
Rural	1	-	-	52.0	-	38.8	39.5
	2 or more	-	61.7	57.5	-	48.5	55.9
ALL		59.7	58.2	51.5	35.1	34.0	40.0

4.2 Running Speeds by Area Type and Facility Type

Running speed is defined as the segment length divided by the segment travel time minus the stopped time (time less than 3 mph). **Tables 12-14** includes the running speed results summarized by roadway functional classification and area type.

Table 12 – AM Weighted Average Running Speed by Area Type, Facility Type, and Lanes AM

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	60.5	55.9	-	35.9	31.7	40.4
CBD (Outlying)	All	60.3	53.2	-	43.3	35.5	40.6
Mixed Urban	All	61.4	59.7	42.6	41.1	38.1	42.5
Suburban	All	-	62.8	50.4	39.5	39.9	44.6
Rural	1	-	-	52.5	-	40.2	41.0
	2 or more	-	63.5	56.6	-	50.1	57.4
ALL		60.6	59.4	50.8	40.7	38.1	43.2

Table 13 – MD Weighted Average Running Speed by Area Type, Facility Type, and Lanes AM

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	-	62.4	-	39.1	32.4	38.6
CBD (Outlying)	All	-	62.6	-	47.3	37.0	41.1
Mixed Urban	All	-	67.0	45.1	42.3	39.3	43.1
Suburban	All	-	66.3	51.4	40.3	41.0	45.0
Rural	1	-	-	51.0	-	41.9	42.6
	2 or more	-	68.8	55.4	-	51.0	58.1
ALL		-	65.9	51.8	42.8	39.7	44.1

Table 14 – PM Weighted Average Running Speed by Area Type, Facility Type, and Lanes AM

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	45.6	42.3	-	37.0	28.7	33.8
CBD (Outlying)	All	59.1	51.2	-	42.8	34.0	39.2
Mixed Urban	All	65.6	60.9	41.9	41.0	37.2	42.6
Suburban	All	-	61.6	52.4	38.3	39.8	44.2
Rural	1	-	-	52.0	-	41.0	41.6
	2 or more	-	61.8	58.0	-	50.3	56.7
ALL		59.8	58.3	52.8	40.2	37.4	42.6

4.3 Posted Speed Limits (Free Flow Speed) by Area Type and Facility Type

For the purpose of calculating delay, the weighted speed limit of a segment is considered the unconstrained travel speed. **Table 15** summarizes the average posted speed limit for each respective roadway facility type by area type and number of lanes. The speed limits and corresponding travel times are used to calculate delay and congestion index. The average speeds shown are weighted by the length of each segment including those instances when the speed changes mid-block.

Table 15 – Average Posted Speed Limits (Free Flow Speed)

Area Type	Lanes	Faciltiy Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	55.0	55.0	-	36.1	34.3	41.2
CBD (Outlying)	All	59.0	59.2	-	43.9	40.5	45.3
Mixed Urban	All	62.6	63.9	50.4	43.5	42.5	47.3
Suburban	All	-	65.7	50.6	45.7	44.2	48.2
Rural	1	-	-	46.5	-	44.4	43.6
	2 or more	-	70.7	56.0	-	45.0	58.6
ALL		59.6	63.8	51.3	43.7	42.3	47.3

4.4 Stop Delay

Stop Delay is one element that is no longer recognized by the *Highway Capacity Manual*, Transportation Research Board, 2000. But, for comparison purposes, it was calculated and defined as the point that the vehicle speed is reduced to 3 mph. The resulting average stop delay (seconds per mile) is shown in **Tables 16-18** according to Area Type/Facility Type

Table 16 – Stop Delay (Seconds per Mile) – AM

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	0.0	1.6	-	38.9	43.7	29.3
CBD (Outlying)	All	0.4	3.2	-	30.3	26.7	20.7
Mixed Urban	All	1.3	1.8	14.3	23.4	20.3	16.5
Suburban	All	-	0.7	3.9	25.1	15.1	12.1
Rural	1	-	-	-	-	12.6	11.8
	2 or more	-	1.0	2.1	-	8.4	4.1
ALL		0.6	1.7	4.5	28.1	20.6	16.1

Table 17 – Stop Delay (Seconds per Mile) – Midday

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	-	0.6	-	34.9	33.9	27.6
CBD (Outlying)	All	-	0.9	-	13.9	18.2	15.6
Mixed Urban	All	-	0.0	9.4	10.2	16.1	13.8
Suburban	All	-	0.2	5.4	21.3	12.0	10.2
Rural	1	-	-	1.4	-	6.9	6.5
	2 or more	-	0.0	1.8	-	5.8	3.2
ALL		-	0.3	4.5	18.3	15.0	12.5

Table 18 – Stop Delay (Seconds per Mile) – PM

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	2.3	9.9	-	54.8	77.1	53.3
CBD (Outlying)	All	1.6	3.6	-	33.8	38.1	29.0
Mixed Urban	All	0.1	0.2	21.6	32.0	25.8	20.1
Suburban	All	-	0.7	4.9	46.7	17.3	14.3
Rural	1	-	-	-	-	11.4	10.7
	2 or more	-	1.0	1.7	-	9.0	4.4
ALL		1.2	1.6	5.1	40.3	27.0	20.8

Tables 19-21 present the delay (seconds per mile) as calculated by segment. Segment delay is the delay experienced while traveling from one point (e.g. intersection) to the next point (intersection). It includes the acceleration delay experienced from the center of the upstream intersection, mid-block delay, the delay while decelerating, the time spent stopped, and the acceleration delay to the center of the downstream intersection. More simply put, segment delay is the difference between travel time at posted speed limit and actual travel time from point A to point B.

Table 19 –Delay (Seconds per Mile) – AM

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	2.4	8.7	-	45.4	63.0	43.4
CBD (Outlying)	All	7.8	28.7	-	44.1	45.0	39.1
Mixed Urban	All	11.3	18.0	30.4	34.5	34.1	30.6
Suburban	All	-	10.3	8.3	47.5	27.9	24.0
Rural	1	-	-	3.4	-	26.6	25.1
	2 or more	-	15.4	4.9	-	12.7	13.4
ALL		8.3	17.6	9.8	43.7	35.2	30.5

Table 20 –Delay (Seconds per Mile) – Midday

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	-	1.0	-	38.4	49.1	39.1
CBD (Outlying)	All	-	4.8	-	16.5	31.5	27.1
Mixed Urban	All	-	1.6	19.6	18.5	27.2	23.6
Suburban	All	-	2.4	9.0	38.4	21.9	18.8
Rural	1	-	-	6.6	-	16.2	15.4
	2 or more	-	2.5	5.0	-	8.9	6.1
ALL		-	2.7	8.7	27.8	25.9	21.9

Table 21 –Delay (Seconds per Mile) – PM

Area Type	Lanes	Facility Type					
		HOV	Freeway	Expressway	6 Leg Arterial	Major Arterial	ALL
CBD	All	45.3	70.4	-	60.8	111.4	93.5
CBD (Outlying)	All	14.4	36.3	-	48.4	62.0	53.4
Mixed Urban	All	1.5	8.9	38.4	43.6	42.4	34.7
Suburban	All	-	13.0	8.6	76.9	30.6	27.2
Rural	1	-	-	3.0	-	23.5	22.3
	2 or more	-	19.6	3.5	-	12.8	15.4
ALL		13.3	19.8	9.3	59.1	44.5	38.0

4.5 Percent Posted Speed

Tables 22-24 include the summary data for Percent Posted Speed by area type/facility type. In contrast to past efforts that summarized results solely on speed, using the mapping effort and subsequent linear reference system that was developed, the Percent Posted Speed was calculated to represent the delay encountered.

Table 22 – Percent Posted Speed– AM

Area Type	Lanes	Facility Type						
		HOV	Freeway	Expressway	Collector	6 Leg Arterial	Major Arterial	ALL
CBD	All	109.9%	100.6%	97.7%	-	82.3%	82.6%	91.7%
CBD (Outlying)	All	101.6%	92.8%	112.1%	70.7%	-	80.3%	84.8%
Mixed Urban	All	103.5%	94.9%	78.1%	83.8%	-	82.8%	86.1%
Suburban	All	-	94.9%	98.0%	93.8%	-	82.8%	86.7%
Rural	1	-	-	112.1%	89.2%	-	84.5%	86.8%
	2 or more	-	90.1%	99.9%	85.4%	-	107.4%	96.4%
ALL		102.7%	93.9%	97.5%	81.8%	82.3%	82.9%	86.7%

Table 23 – Percent Posted Speed– Midday

Area Type	Lanes	Facility Type						
		HOV	Freeway	Expressway	Collector	6 Leg Arterial	Major Arterial	ALL
CBD	All	-	112.9%	102.2%	-	88.7%	85.7%	93.3%
CBD (Outlying)	All	-	106.6%	111.2%	95.2%	-	86.4%	90.5%
Mixed Urban	All	-	107.2%	84.2%	84.6%	-	85.8%	89.5%
Suburban	All	-	100.7%	98.3%	97.8%	-	86.0%	89.6%
Rural	1	-	-	108.1%	106.2%	-	89.5%	91.7%
	2 or more	-	97.9%	99.3%	96.7%	-	110.3%	103.2%
ALL		-	103.6%	98.5%	93.1%	88.7%	87.1%	90.9%

Table 24 – Percent Posted Speed– PM

Area Type	Lanes	Facility Type						
		HOV	Freeway	Expressway	Collector	6 Leg Arterial	Major Arterial	ALL
CBD	All	82.3%	75.6%	105.7%	-	75.4%	71.6%	74.3%
CBD (Outlying)	All	100.1%	83.1%	104.7%	94.9%	-	75.8%	80.5%
Mixed Urban	All	110.6%	97.8%	76.6%	93.2%	-	79.4%	85.0%
Suburban	All	-	93.1%	100.2%	94.0%	-	82.3%	85.8%
Rural	1	-	-	112.9%	92.3%	-	88.7%	90.5%
	2 or more	-	87.6%	103.6%	96.4%	-	108.5%	95.4%
ALL		101.6%	91.2%	100.2%	93.9%	75.4%	80.3%	84.6%

4.6 Travel Time Between Cities

The travel time between the central business districts for ten communities and the Sky Harbor Airport were computed. The 2007 Travel Time and Travel Speed Study was comprehensive in nature and represents the speeds on all arterials and freeways within the MAG region. Therefore, this data joined with the extensive GIS network and linear reference system allows various elements to be calculated. This is a lengthy computer process and for example purposes, **Figures 37-39** are included to demonstrate the format of the travel time contours, additional figures are included in Appendix A for various cities. **Tables 25-30** include the travel times (in minutes) for the AM and PM Periods from/to each respective city centroid.

Table 25 – AM Place-to-Place Travel Time Matrix

	Avondale	Chandler	Gilbert	Glendale	Mesa	Peoria	Phoenix	Scottsdale	Sky Harbo	Sun City	Tempe
Avondale	-	56.9	58.3	24.2	48.8	21.1	33.2	47.1	39.9	22.3	44.9
Chandler	53.2	-	11.0	50.2	16.4	54.8	34.9	31.7	34.1	57.5	24.0
Gilbert	52.8	11.3	-	49.8	14.6	54.5	34.6	30.1	33.7	57.2	22.4
Glendale	22.7	47.6	49.0	-	39.5	8.7	24.7	37.8	30.6	14.5	35.6
Mesa	42.5	15.2	13.3	39.5	-	45.4	27.0	17.4	26.2	46.9	11.3
Peoria	20.3	53.3	54.7	10.0	45.2	-	30.4	43.5	36.3	6.4	41.4
Phoenix	22.0	30.5	31.9	19.0	22.4	23.9	-	20.7	10.1	26.4	18.5
Scottsdale	36.4	22.7	24.1	33.4	15.4	39.1	21.0	-	21.2	40.8	12.5
Sky Harbor	27.1	30.5	29.8	24.1	22.5	29.9	9.9	20.4	-	31.5	18.6
Sun City	22.4	59.7	61.1	16.2	51.6	6.4	36.8	49.9	42.7	-	47.7
Tempe	35.1	20.1	21.5	32.1	12.8	36.8	16.9	11.8	16.0	39.5	-

Table 26 – AM Hour 1 Place-to-Place Travel Time Matrix

	Avondale	Chandler	Gilbert	Glendale	Mesa	Peoria	Phoenix	Scottsdale	Sky Harbor	Sun City	Tempe
Avondale	-	59.5	60.5	24.8	51.7	21.7	34.3	49.3	42.0	22.8	47.1
Chandler	54.0	-	10.4	51.0	17.5	55.6	35.5	31.8	34.6	58.5	24.1
Gilbert	55.2	11.5	-	52.1	14.3	56.7	36.7	29.8	35.8	59.6	24.2
Glendale	22.5	47.6	48.6	-	39.7	8.5	23.9	37.3	30.2	14.7	35.2
Mesa	42.6	16.7	13.5	39.5	-	45.3	26.9	16.9	26.3	47.1	11.5
Peoria	20.6	56.5	57.5	10.2	48.6	-	32.8	46.2	39.1	6.7	44.1
Phoenix	22.1	30.7	31.0	19.0	22.9	24.1	-	20.5	9.8	26.5	18.3
Scottsdale	36.4	22.9	23.9	32.8	15.9	37.9	20.4	-	20.5	40.9	12.9
Sky Harbor	26.3	29.5	28.7	23.3	22.0	29.0	9.0	19.1	-	30.8	17.5
Sun City	22.6	62.8	63.8	16.1	55.0	6.3	39.2	52.6	45.4	-	50.4
Tempe	35.5	20.6	21.6	32.4	13.6	37.0	17.0	11.7	16.0	39.9	-

Table 27 – AM Hour 2 Place-to-Place Travel Time Matrix

	Avondale	Chandler	Gilbert	Glendale	Mesa	Peoria	Phoenix	Scottsdale	Sky Harbor	Sun City	Tempe
Avondale	-	56.5	57.9	24.9	48.8	21.1	33.5	47.2	39.9	22.3	45.5
Chandler	54.0	-	11.9	52.0	18.6	56.8	36.1	36.0	35.2	58.9	26.4
Gilbert	52.9	11.7	-	51.0	15.7	55.7	35.0	33.0	34.2	57.9	25.3
Glendale	22.7	48.9	50.2	-	41.1	8.9	25.3	39.5	32.2	14.9	37.9
Mesa	43.4	16.6	13.4	41.4	-	47.2	28.5	19.8	27.7	48.4	15.6
Peoria	20.1	54.9	56.2	11.2	47.2	-	30.4	45.5	38.3	6.5	43.9
Phoenix	22.2	31.1	31.6	20.1	23.4	24.7	-	21.7	10.4	27.2	20.1
Scottsdale	37.1	23.6	24.9	35.1	16.8	40.9	22.2	-	22.4	42.0	12.6
Sky Harbor	26.6	30.6	30.1	24.6	22.9	30.4	10.4	21.2	-	31.5	19.5
Sun City	22.7	61.7	63.0	17.6	53.9	6.8	37.1	52.3	45.0	-	50.7
Tempe	34.9	20.8	22.1	32.9	14.0	37.7	17.0	13.0	16.2	39.9	-

Table 28 – PM Place-to-Place Travel Time Matrix

	Avondale	Chandler	Gilbert	Glendale	Mesa	Peoria	Phoenix	Scottsdale	Sky Harbo	Sun City	Tempe
Avondale	-	57.8	58.1	23.8	44.6	21.7	23.2	39.5	29.9	24.1	38.2
Chandler	58.9	-	10.2	53.6	16.6	59.5	31.3	24.0	29.2	63.0	21.0
Gilbert	57.8	11.4	-	52.5	15.5	58.4	30.2	24.2	28.1	61.9	21.0
Glendale	27.4	56.6	57.0	-	43.5	8.7	21.8	35.9	27.5	16.9	37.1
Mesa	54.0	18.4	16.6	47.5	-	53.4	25.7	15.9	23.5	56.5	13.2
Peoria	25.0	61.4	61.7	8.9	48.2	-	26.1	40.8	31.7	8.6	41.9
Phoenix	31.5	42.1	41.5	24.6	29.6	30.5	-	24.5	9.8	34.0	23.2
Scottsdale	53.9	33.5	33.1	42.6	20.7	48.7	23.9	-	22.4	56.4	14.9
Sky Harbor	39.9	40.9	39.9	34.6	28.8	40.5	10.4	23.7	-	44.0	22.5
Sun City	26.5	62.9	63.2	15.3	49.7	6.4	28.3	44.6	35.0	-	43.4
Tempe	47.2	24.7	24.1	41.9	14.3	47.8	19.6	13.3	17.5	51.3	-

Table 29 – PM Hour 1 Place-to-Place Travel Time Matrix

	Avondale	Chandler	Gilbert	Glendale	Mesa	Peoria	Phoenix	Scottsdale	Sky Harbor	Sun City	Tempe
Avondale	-	56.9	57.4	24.8	43.6	22.4	24.6	41.0	29.8	26.5	40.1
Chandler	61.4	-	10.6	56.1	17.1	62.8	32.2	24.5	29.8	67.2	22.4
Gilbert	60.1	10.7	-	54.8	15.5	61.5	30.9	24.5	28.5	65.9	21.7
Glendale	26.5	56.7	57.2	-	43.3	8.2	23.0	35.9	27.6	18.6	39.8
Mesa	55.8	19.5	16.8	50.1	-	56.8	24.9	16.2	24.4	61.0	14.2
Peoria	24.0	60.6	61.0	9.1	47.2	-	27.1	41.6	31.8	10.5	43.7
Phoenix	31.1	41.4	41.9	25.2	28.1	31.9	-	25.5	9.9	36.3	23.1
Scottsdale	54.5	33.0	33.4	44.9	20.0	50.3	23.4	-	22.9	58.1	14.7
Sky Harbor	41.5	39.7	40.2	35.6	26.4	42.3	10.4	23.8	-	46.6	22.7
Sun City	25.6	62.2	62.6	16.1	48.8	7.0	29.9	46.3	35.0	-	45.3
Tempe	51.0	25.1	24.5	45.1	14.5	51.8	19.9	13.5	19.4	56.2	-

Table 30 – PM Hour 2 Place-to-Place Travel Time Matrix

	Avondale	Chandler	Gilbert	Glendale	Mesa	Peoria	Phoenix	Scottsdale	Sky Harbor	Sun City	Tempe
Avondale	-	59.8	59.8	22.9	48.8	21.4	23.5	40.6	30.5	23.0	42.4
Chandler	61.0	-	10.8	54.4	17.7	60.7	31.5	28.4	29.4	62.3	21.0
Gilbert	59.6	11.7	-	53.0	15.6	59.3	30.1	28.3	28.0	60.9	20.9
Glendale	28.5	57.6	57.6	-	46.6	9.9	21.3	38.2	27.7	16.4	40.2
Mesa	57.3	19.9	17.7	49.5	-	55.9	23.4	19.2	22.9	57.4	13.9
Peoria	27.6	63.6	63.6	8.8	52.6	-	26.7	43.1	32.6	7.9	46.2
Phoenix	33.9	42.5	42.5	26.1	31.5	32.5	-	25.8	10.0	34.1	25.1
Scottsdale	57.6	33.9	33.9	45.4	22.8	52.6	23.6	-	23.9	57.7	18.5
Sky Harbor	40.7	40.4	40.3	34.0	30.7	40.4	9.4	23.6	-	42.0	23.0
Sun City	28.8	64.9	64.9	15.4	53.9	6.6	28.6	45.7	35.6	-	47.5
Tempe	49.8	25.3	25.3	43.2	16.1	49.6	18.6	14.8	18.1	51.2	-

Figure 37 - Travel Time Contours - Phoenix Inbound AM

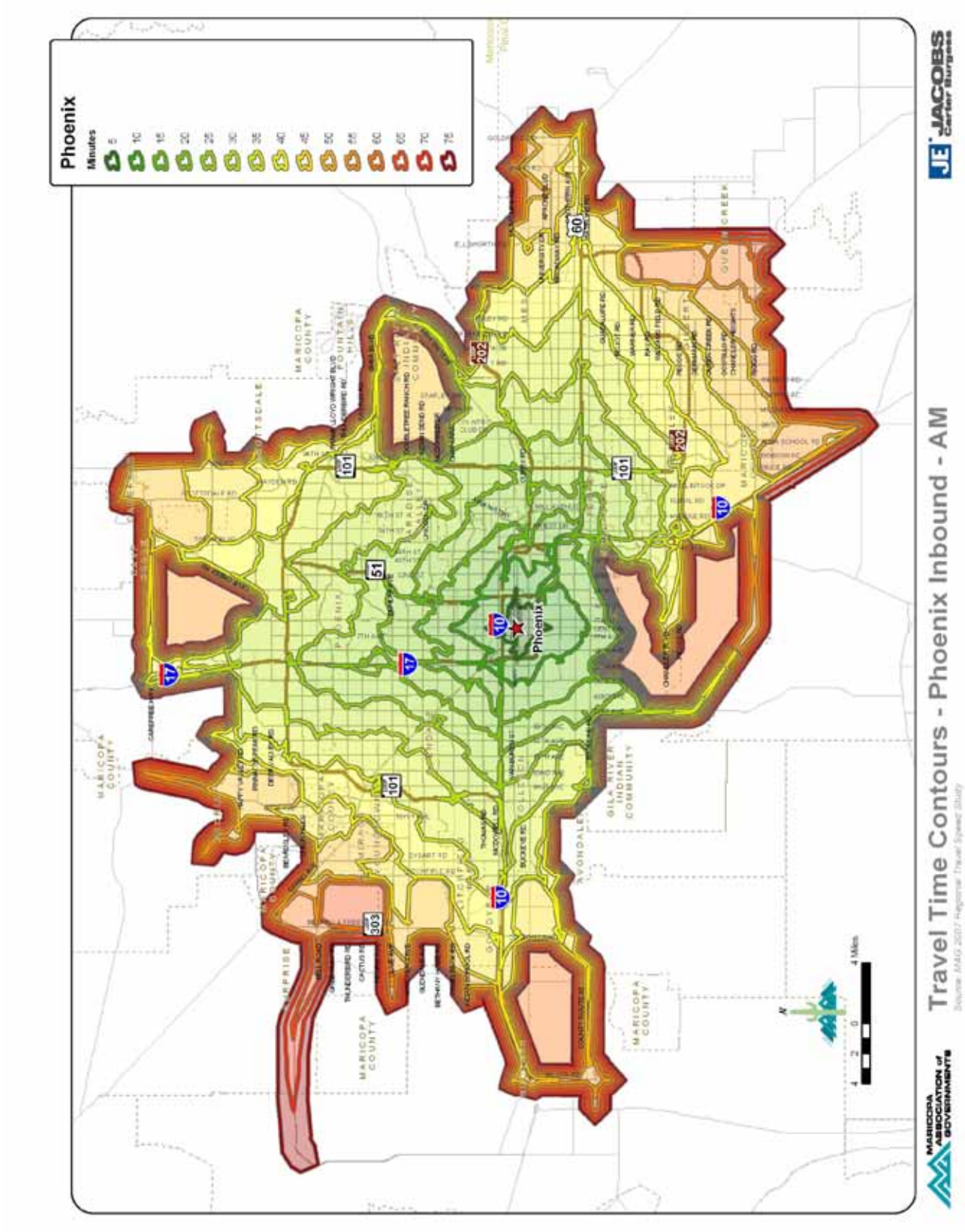


Figure 38 - Travel Time Contours - Phoenix Inbound Free Flow (Posted Speed Limit)

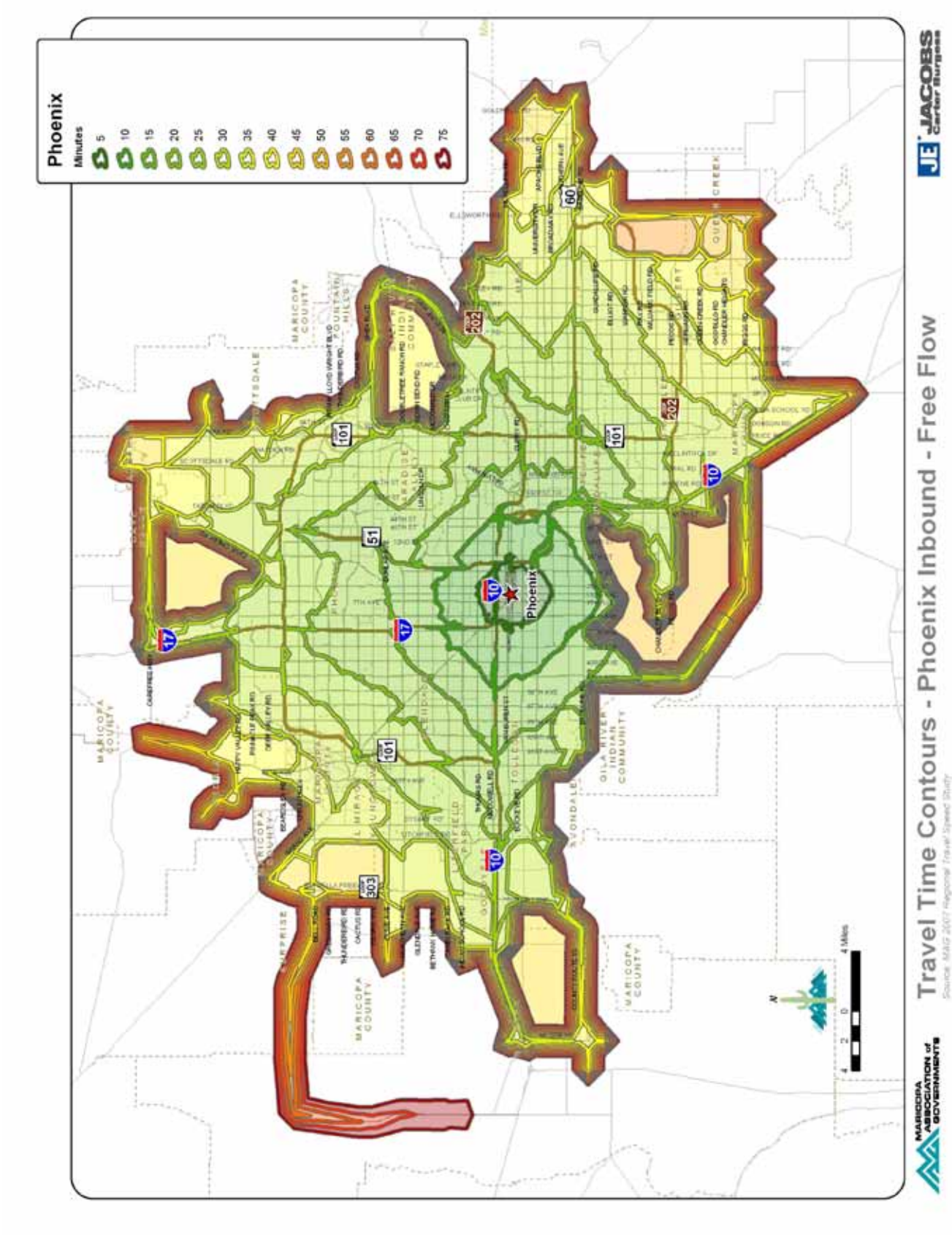
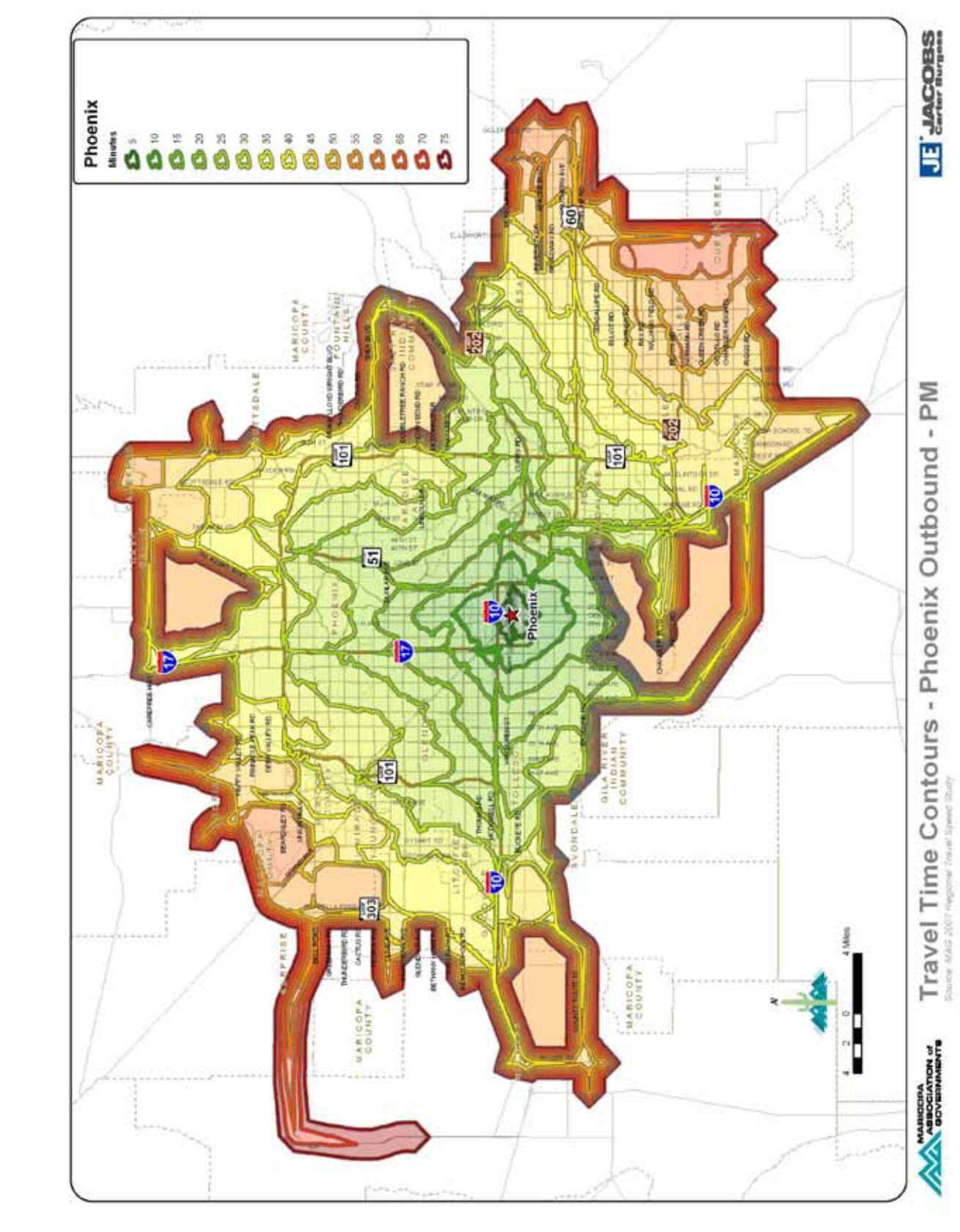


Figure 39 - Travel Time Contours - Phoenix Outbound PM



5.0 Traffic Delay at Intersections

5.1 Segment Delay

The 2002-2003 Regional Travel Time and Travel Speed Study established the segment delay as the preferred approximation of the control delay associated at intersections. According to Hoeschen, Bullock, and Schlappi[1], this segment delay estimation is appropriate for large travel speed studies. Segment delay is the delay experienced while traveling from one point (e.g. intersection) to the next point (intersection). It includes the acceleration delay experienced from the center of the upstream intersection, mid-block delay, the delay while decelerating, the time spent stopped, and the acceleration delay to the center of the downstream intersection. More simply put, segment delay is the difference between travel time at posted speed limit and actual travel time from point A to point B.

Figures 40-52 illustrate the delay for each segment on the arterials and freeways. For freeway segments, the delay is on a per mile basis. Additional figures are included for reference for the PM period that provides more detail of various quadrants of the study region.

Using the segment delay along with available link volumes (provided by MAG), the LOS was calculated and shown in **Figures 53-55** for the AM, MD, and PM time periods, respectively.

Figure 40 – Average Arterial Segment Delay - AM

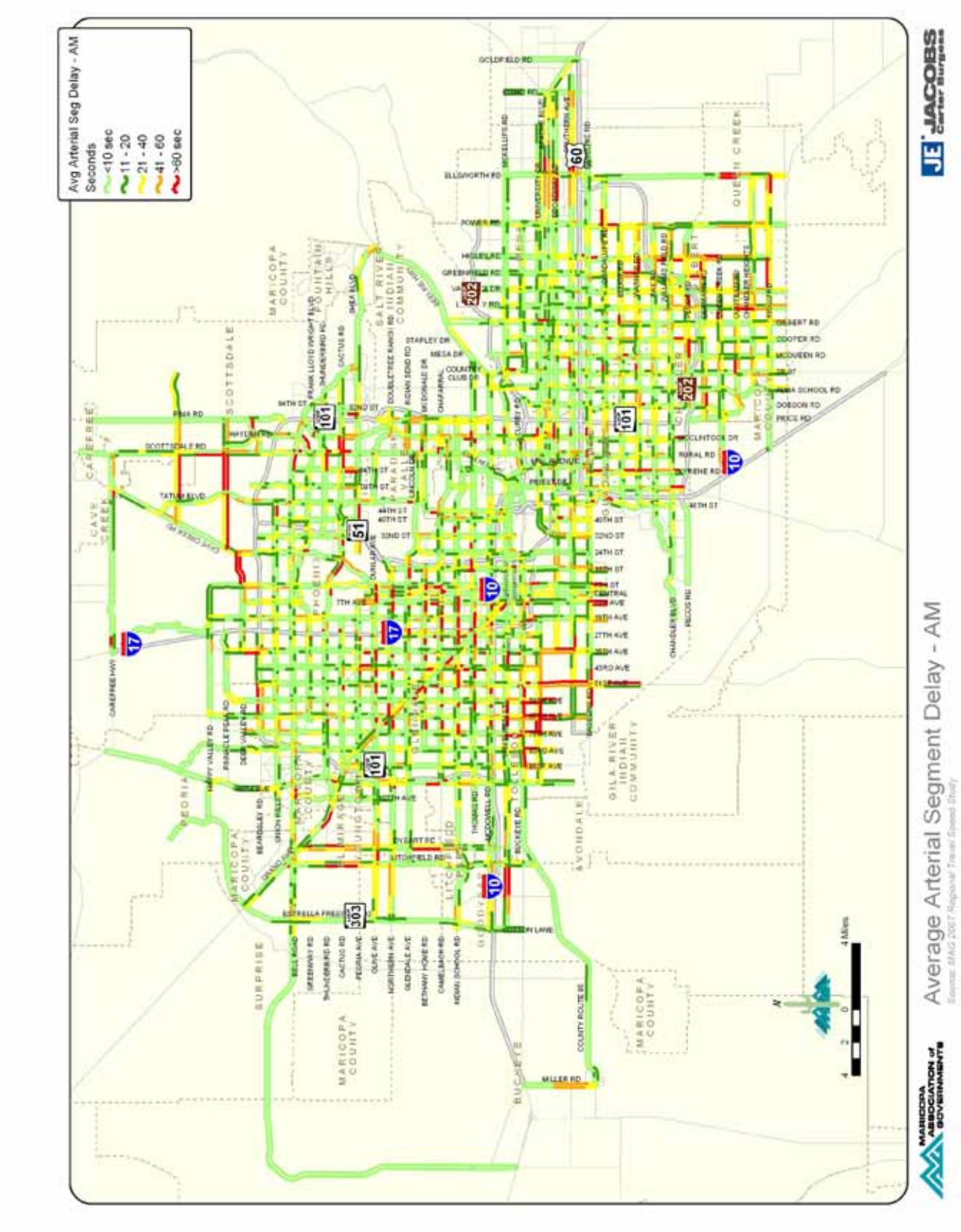


Figure 41 –Average Arterial Segment Delay - Mid-Day

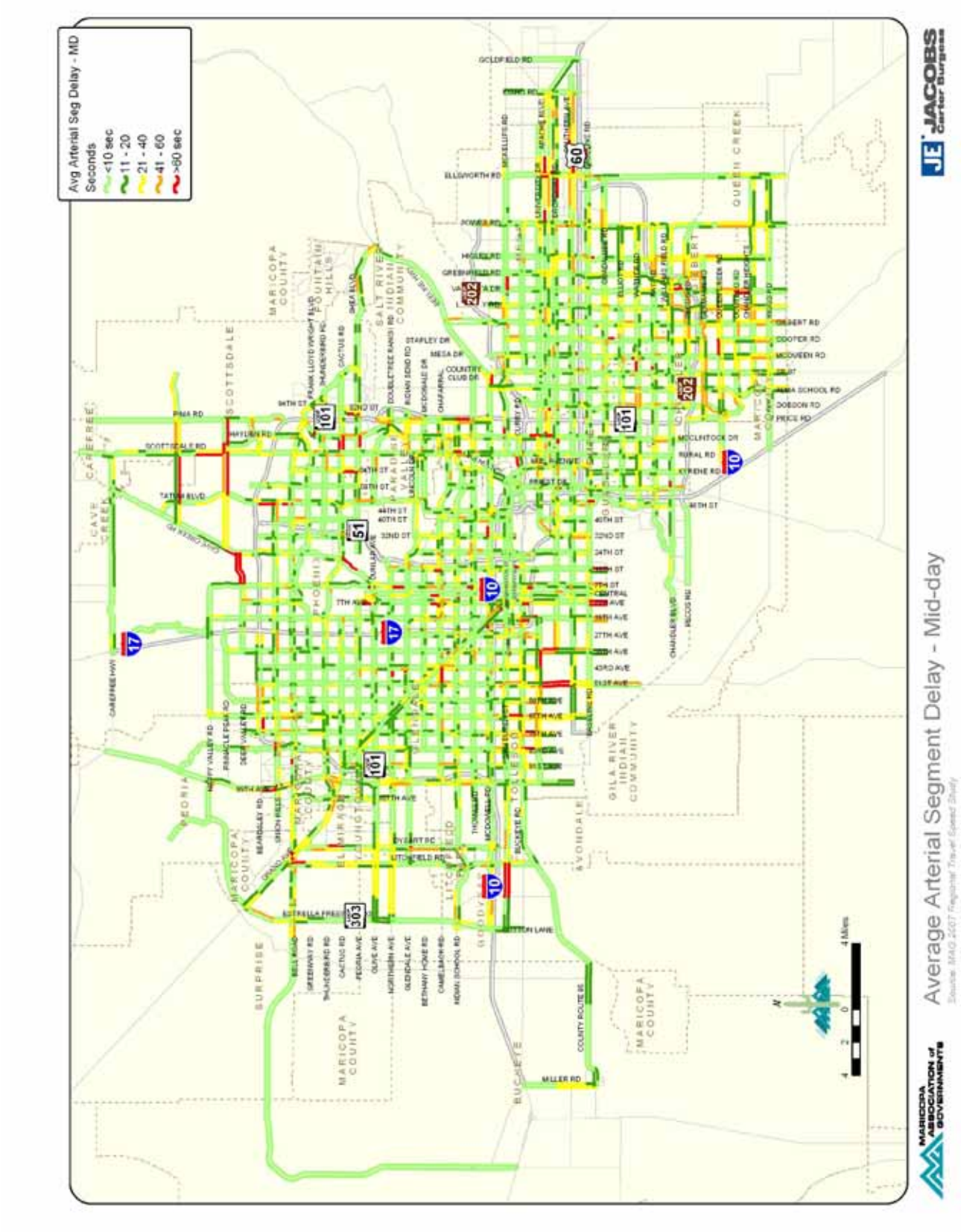


Figure 42 - Average Arterial Segment Delay - PM

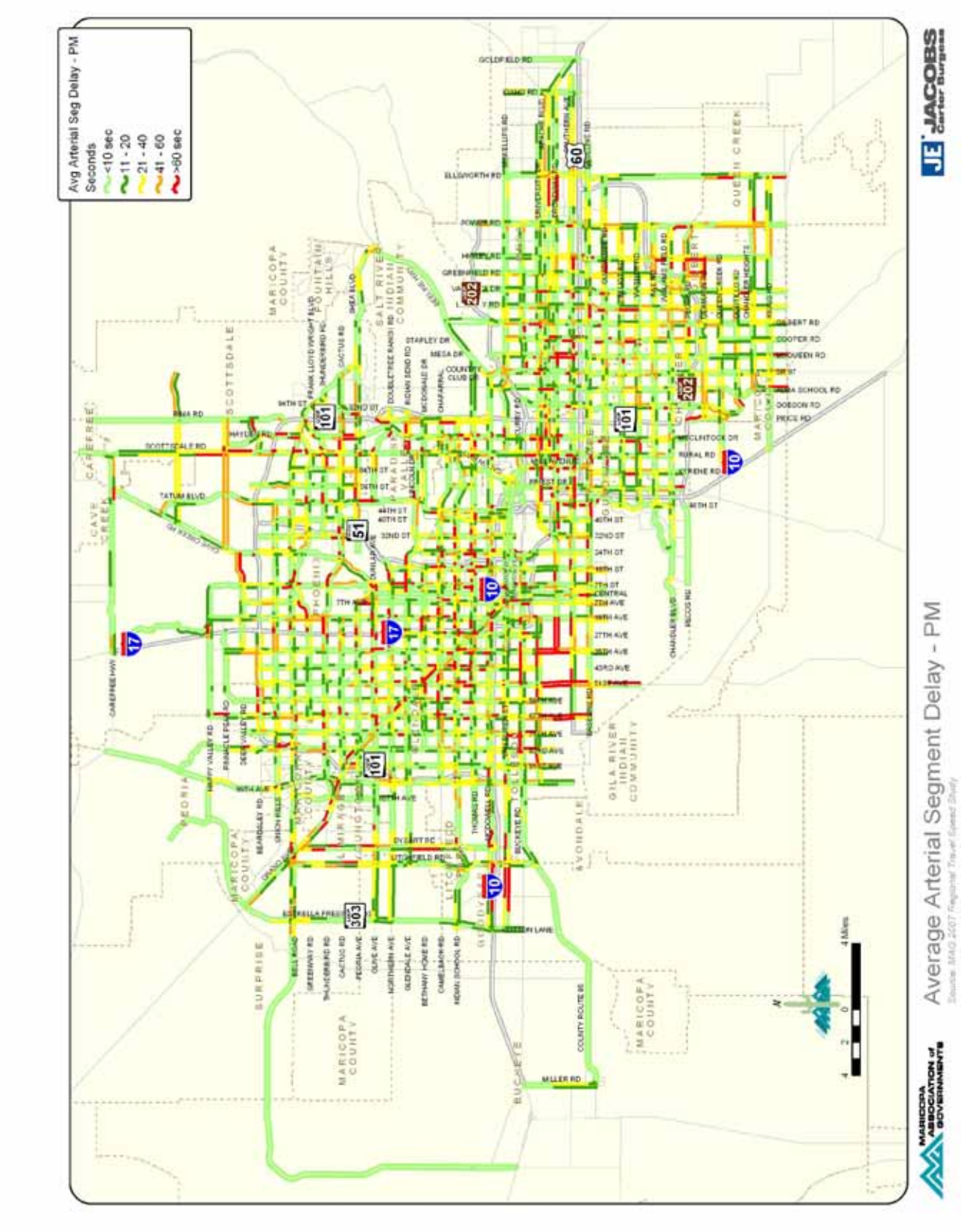


Figure 43 - Average Arterial Segment Delay – PM Detail (Map 1 of 7)

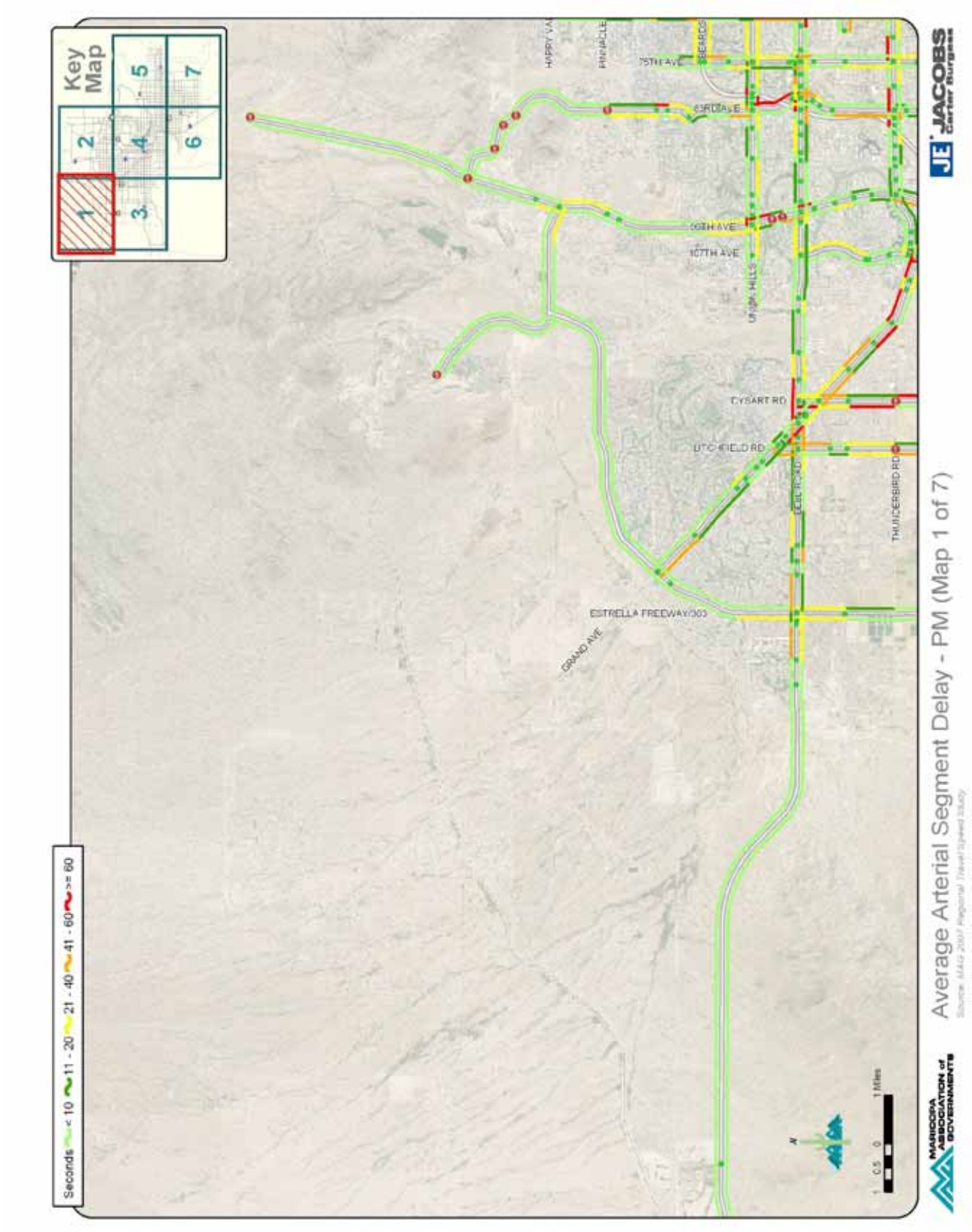


Figure 44 - Average Arterial Segment Delay – PM Detail (Map 2 of 7)

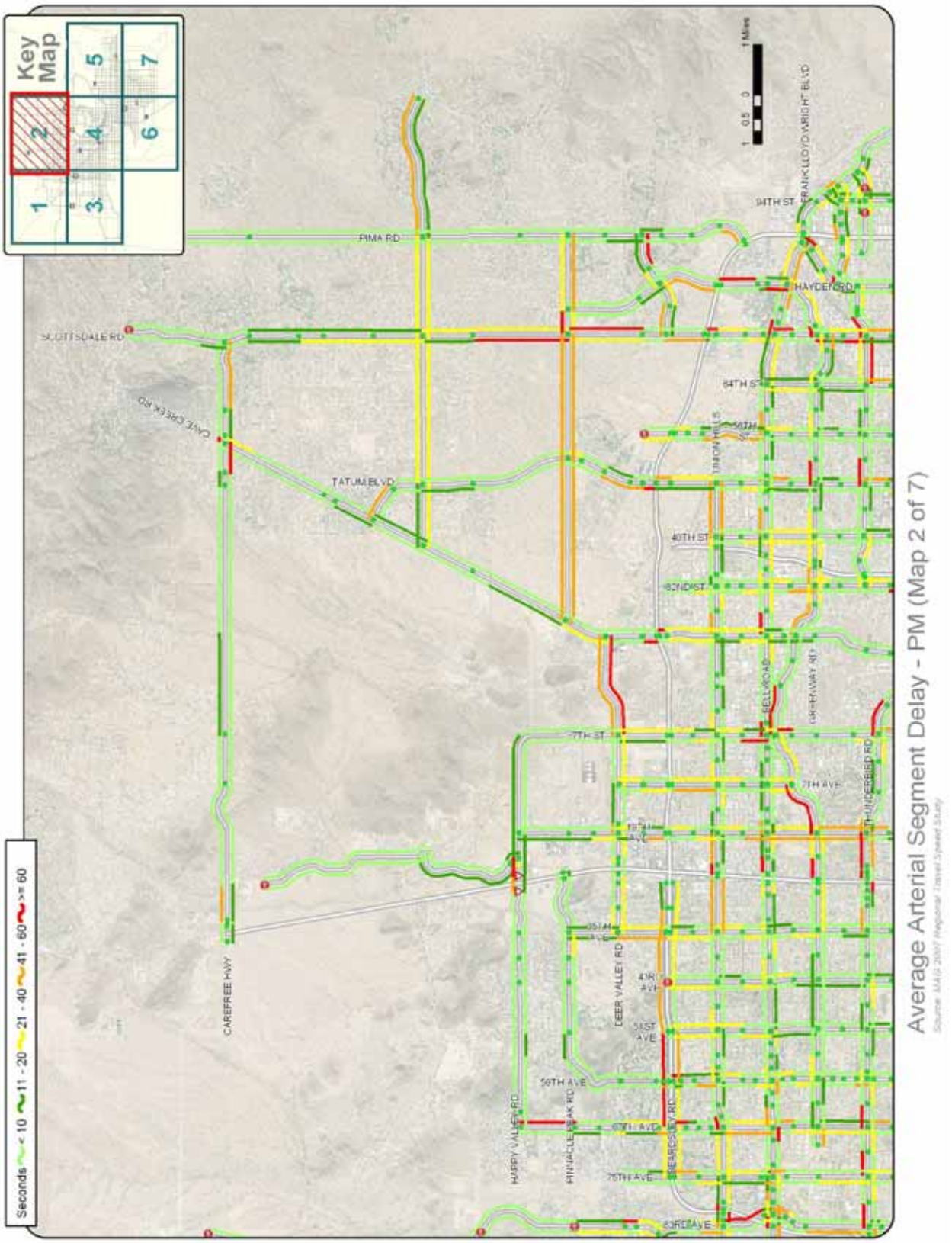


Figure 45 - Average Arterial Segment Delay – PM Detail (Map 3 of 7)

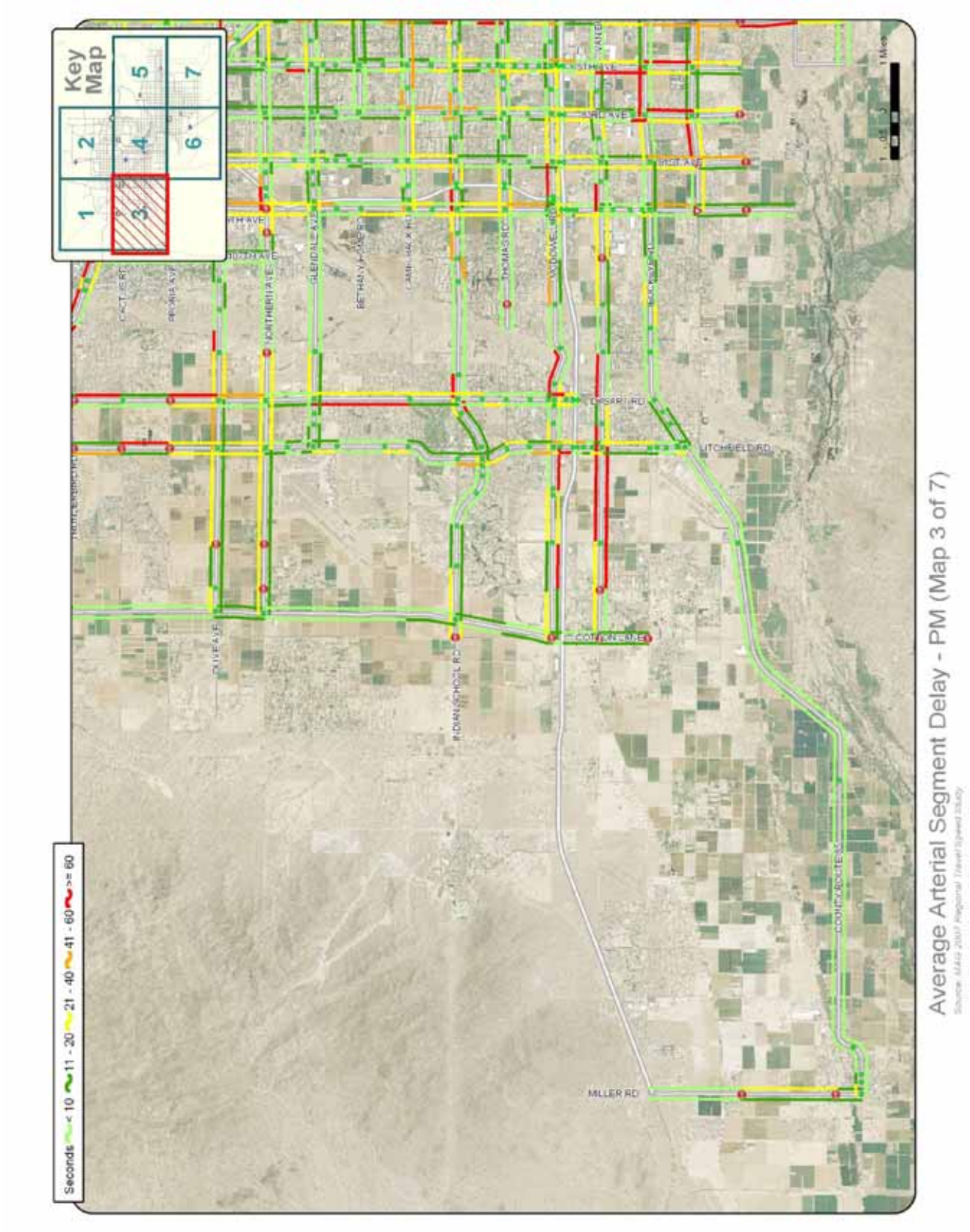


Figure 46 - Average Arterial Segment Delay – PM Detail (Map 4 of 7)

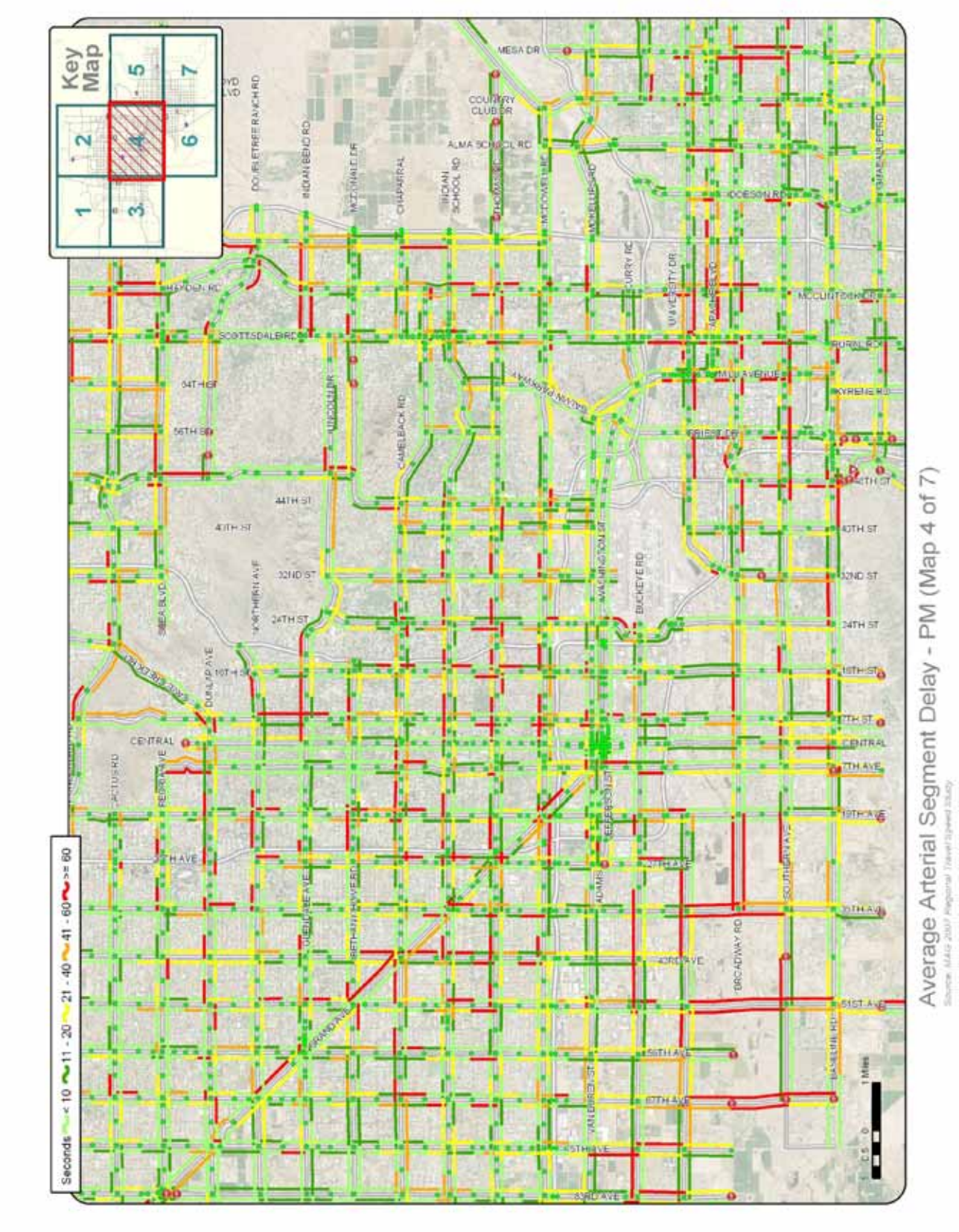


Figure 47 - Average Arterial Segment Delay – PM Detail (Map 5 of 7)

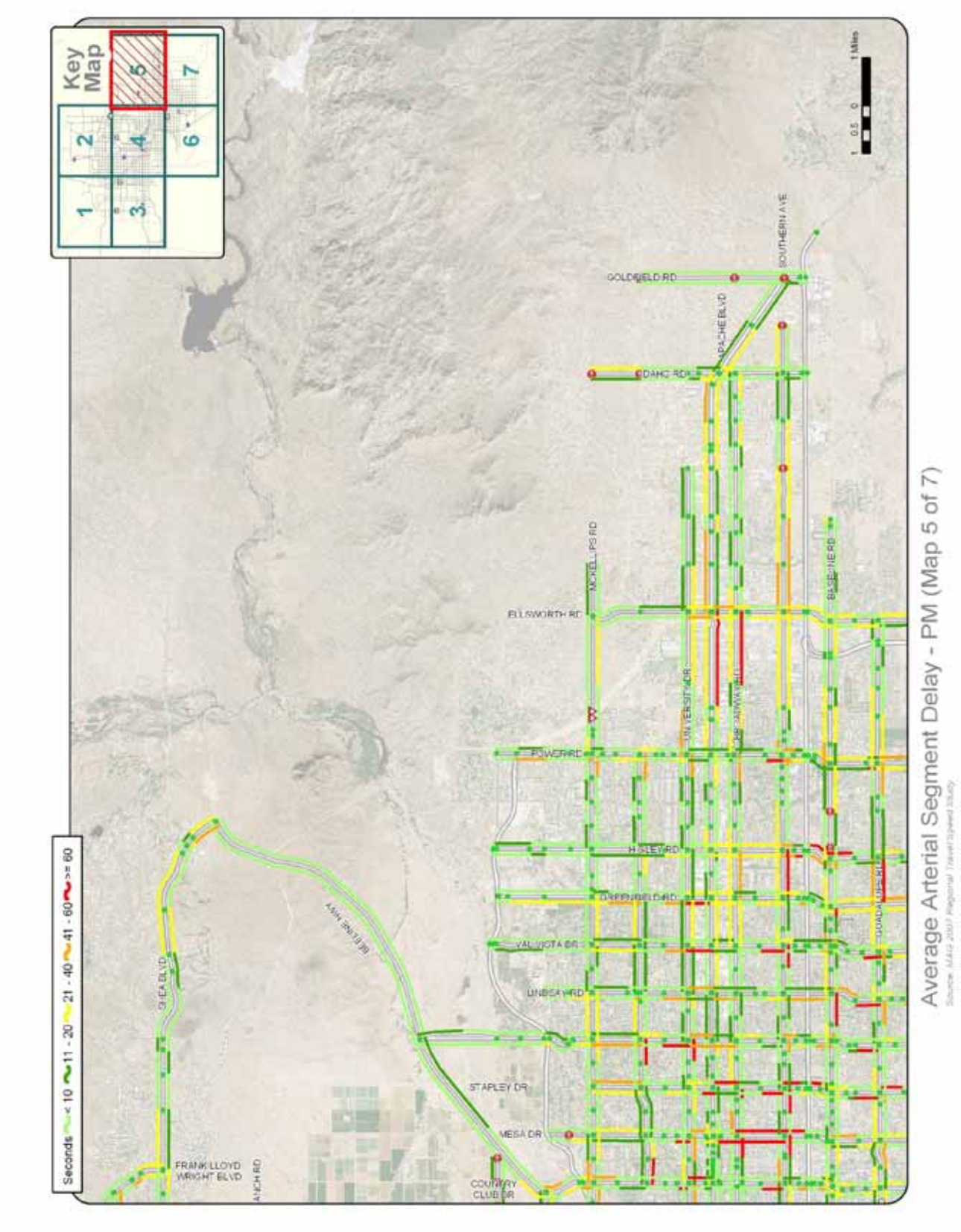


Figure 48 - Average Arterial Segment Delay – PM Detail (Map 6 of 7)

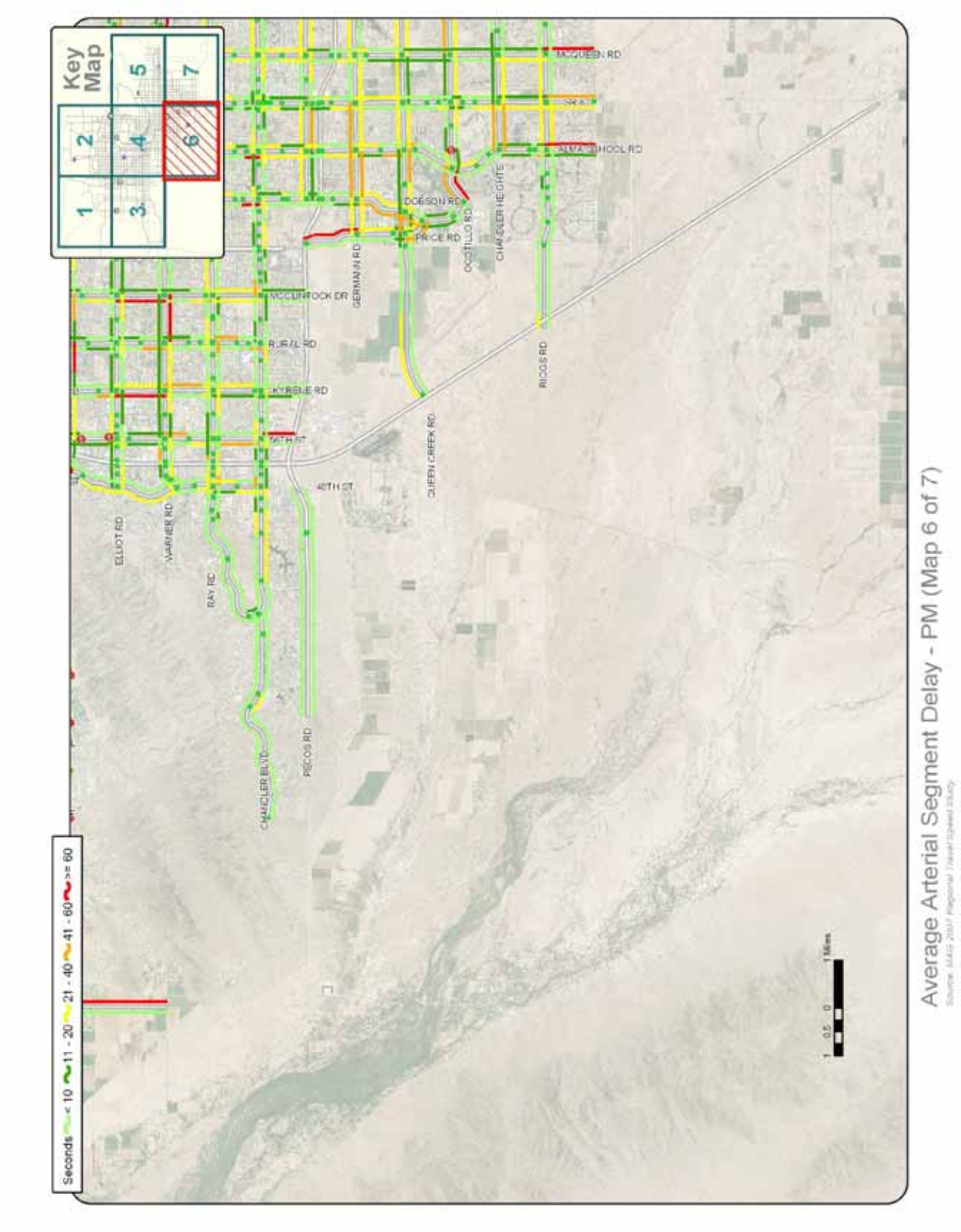


Figure 49 - Average Arterial Segment Delay – PM Detail (Map 7 of 7)

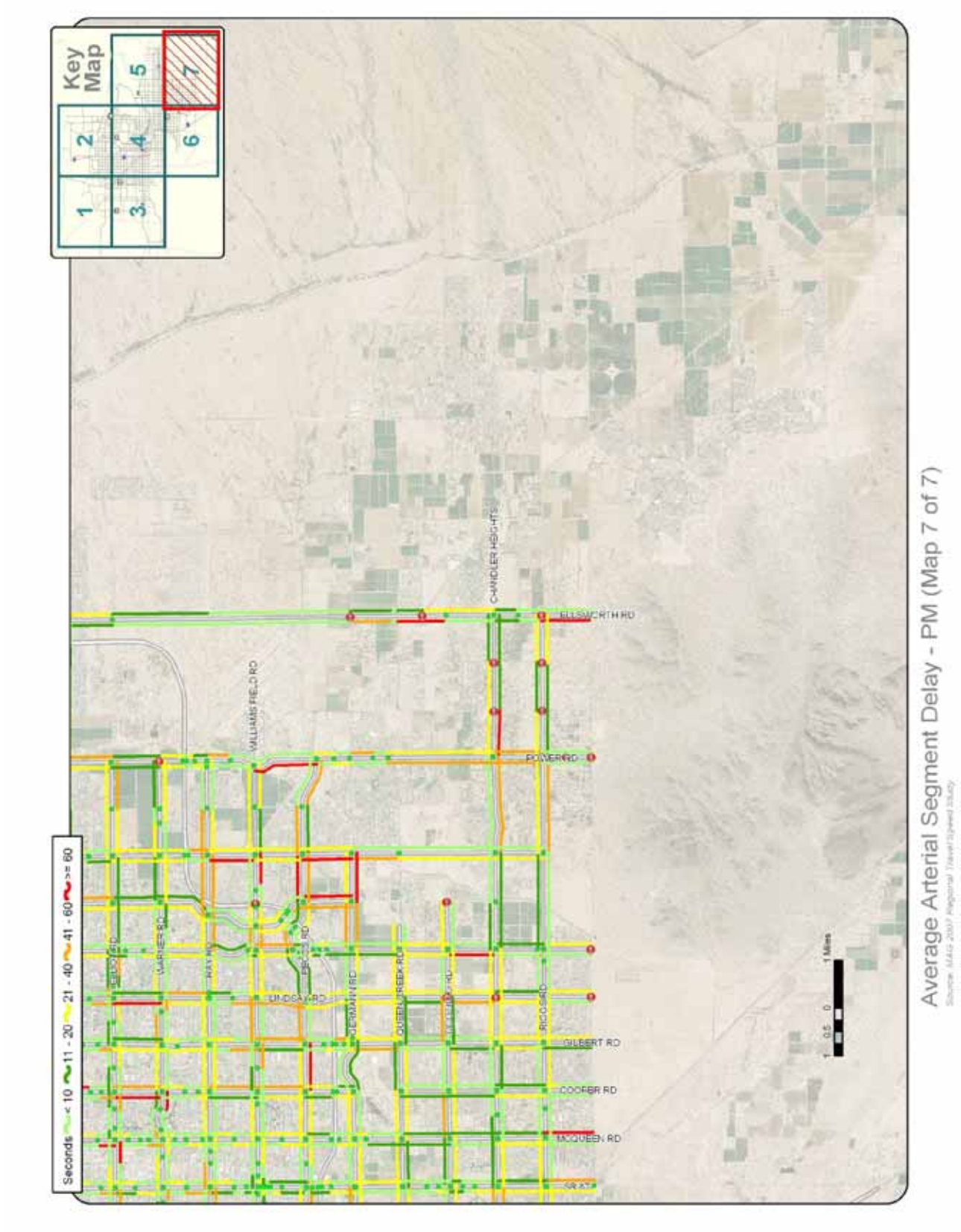


Figure 50 - Average Freeway Segment Delay per Mile – AM

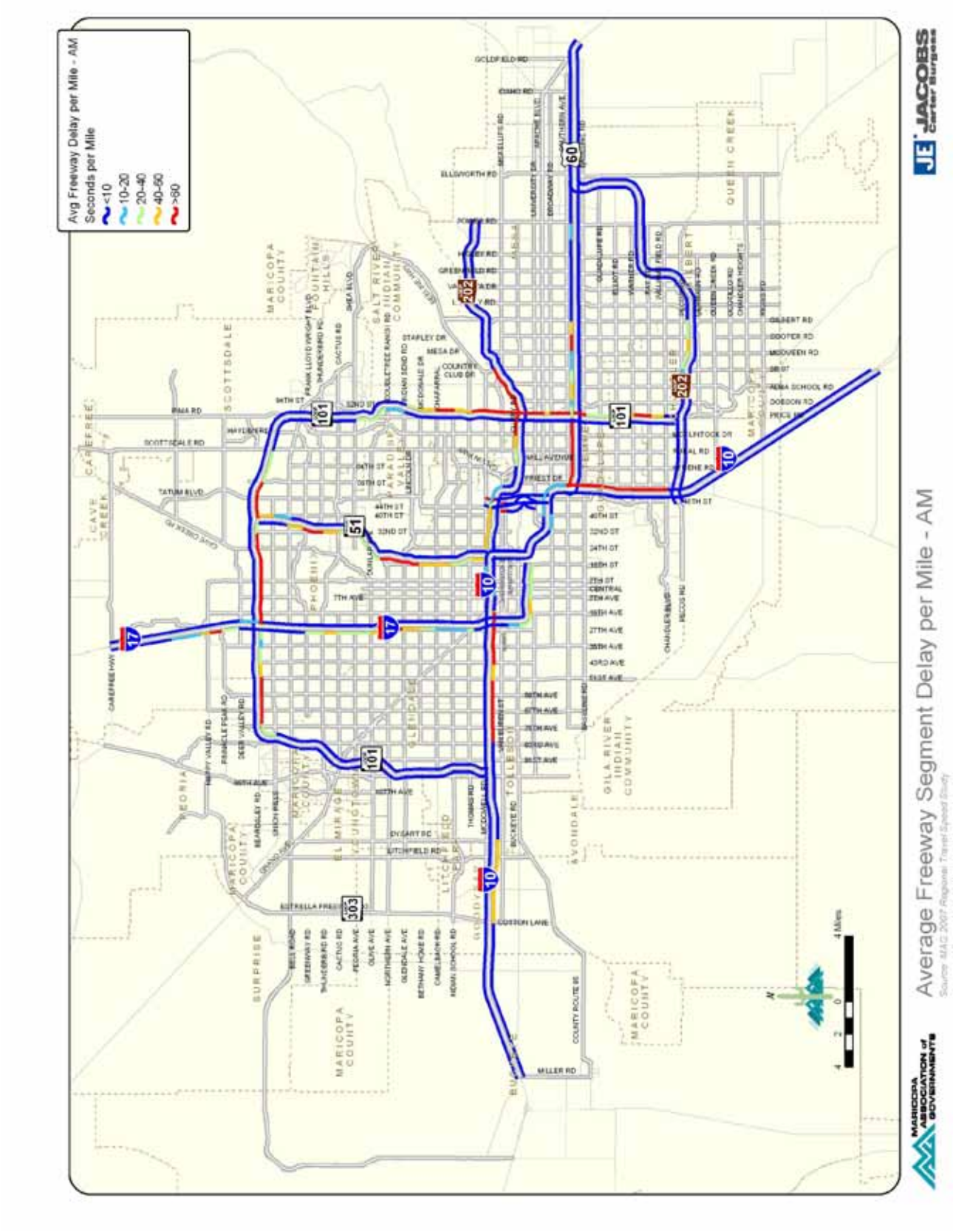


Figure 51 - Average Freeway Segment Delay per Mile – Mid-Day

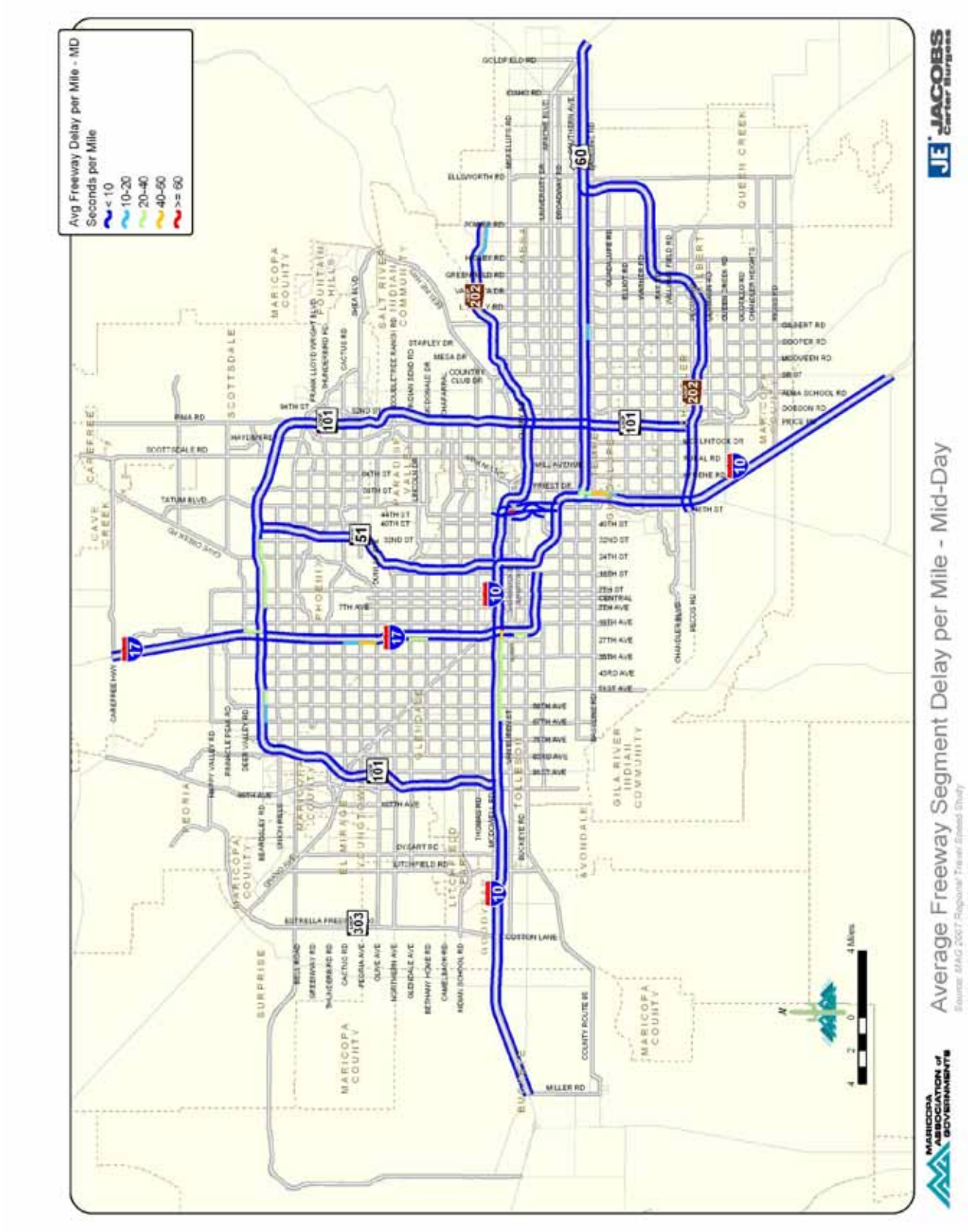


Figure 52 - Average Freeway Segment Delay per Mile – PM

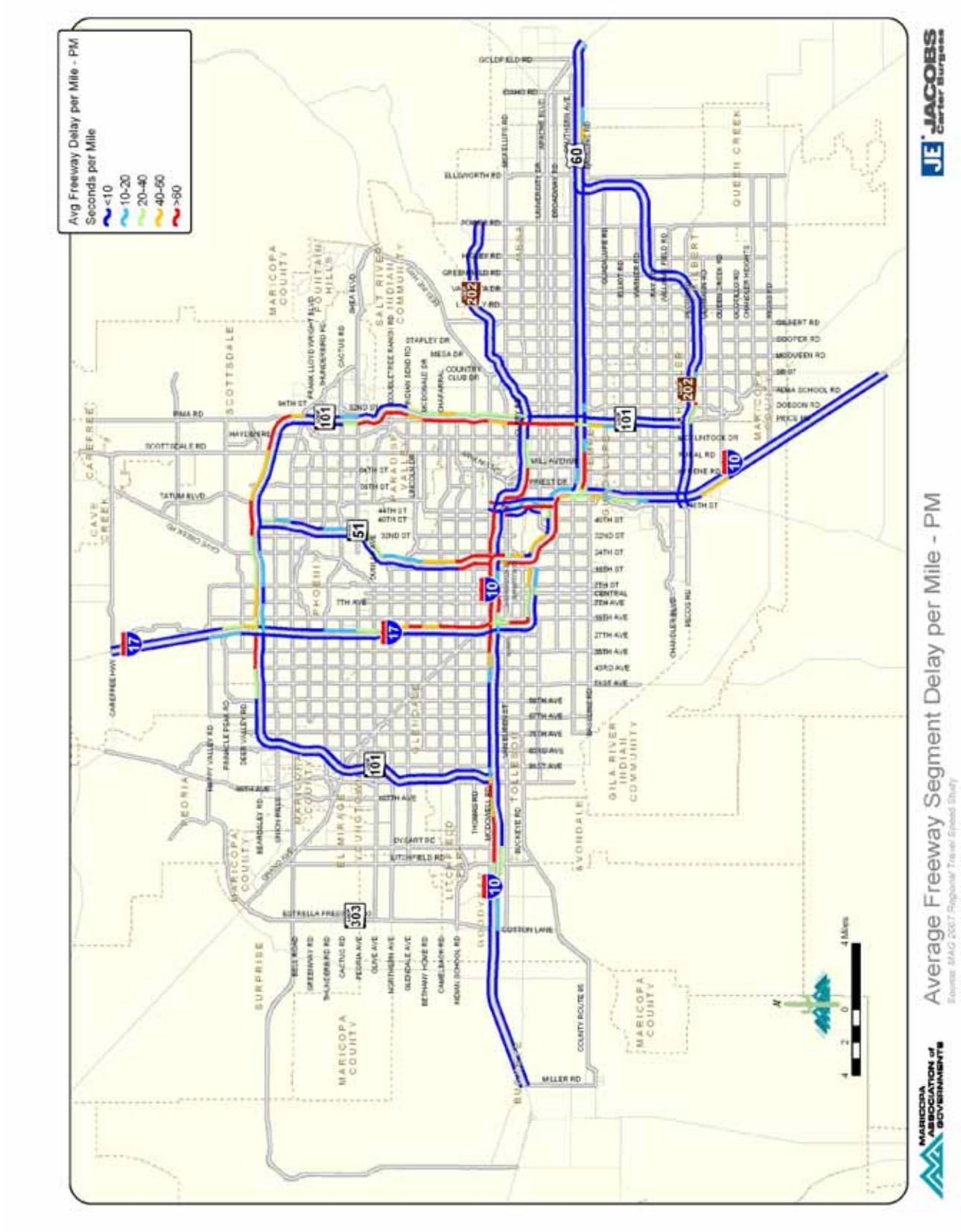


Figure 53 – Intersection LOS – AM

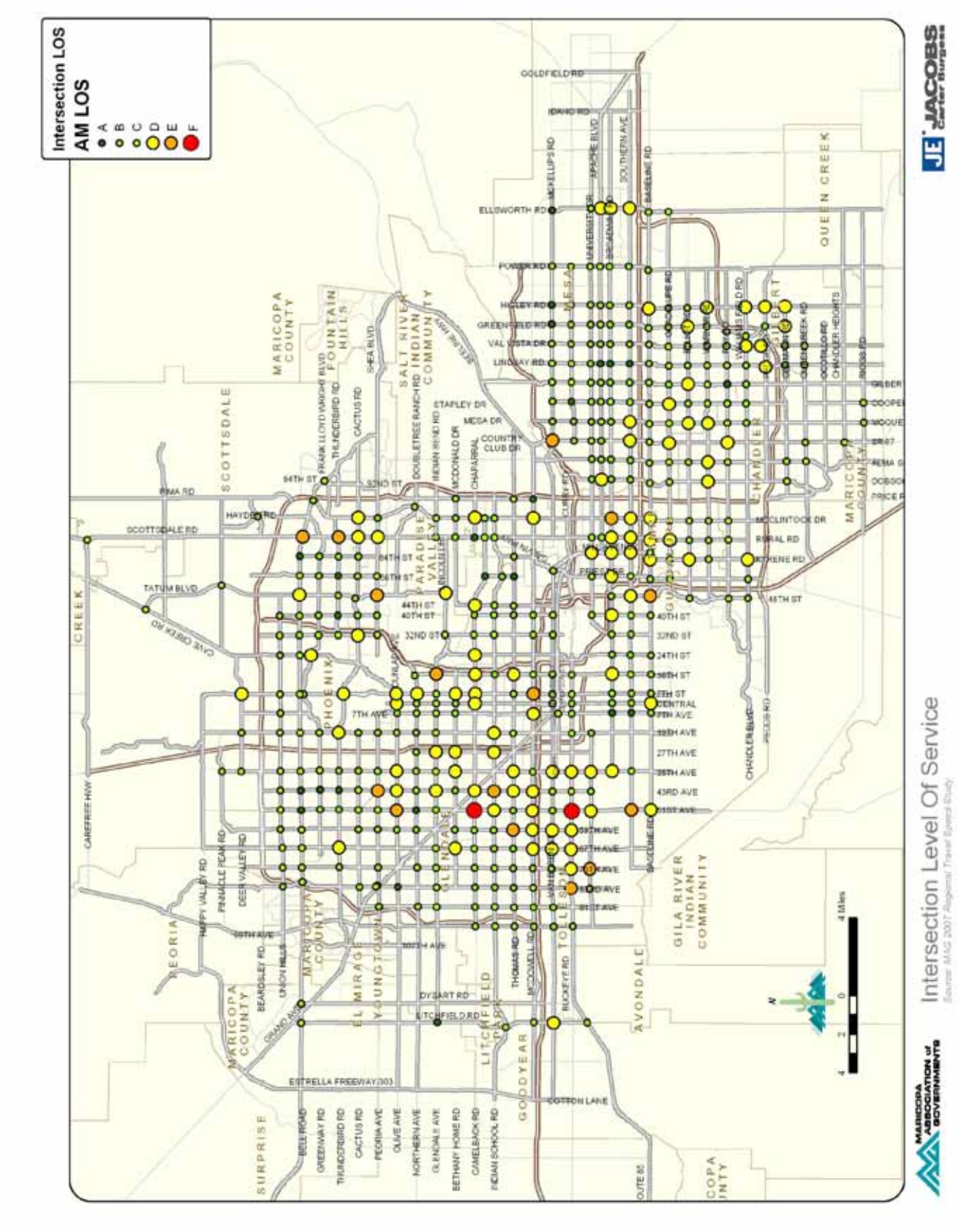


Figure 54 – Intersection LOS – Mid-Day

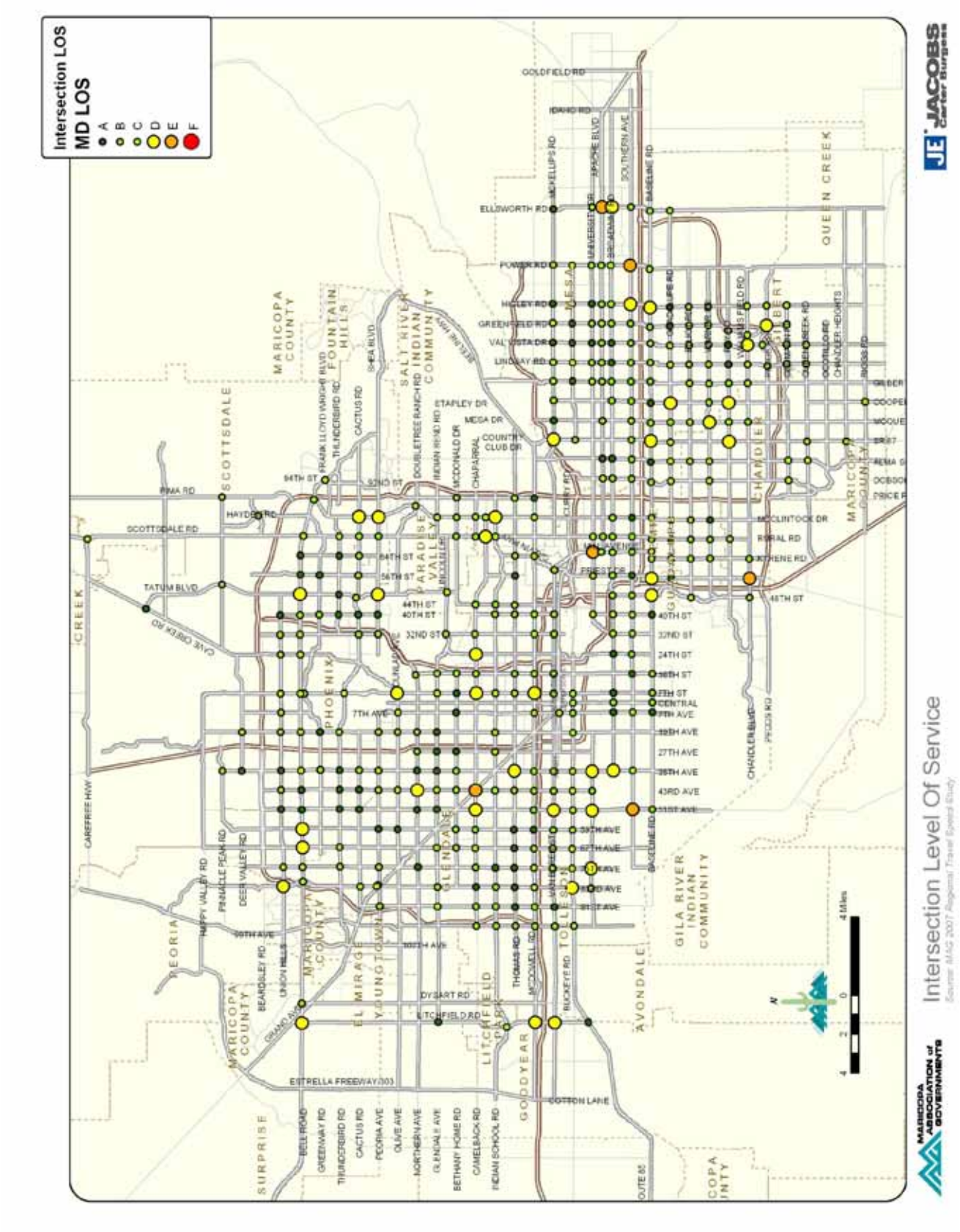
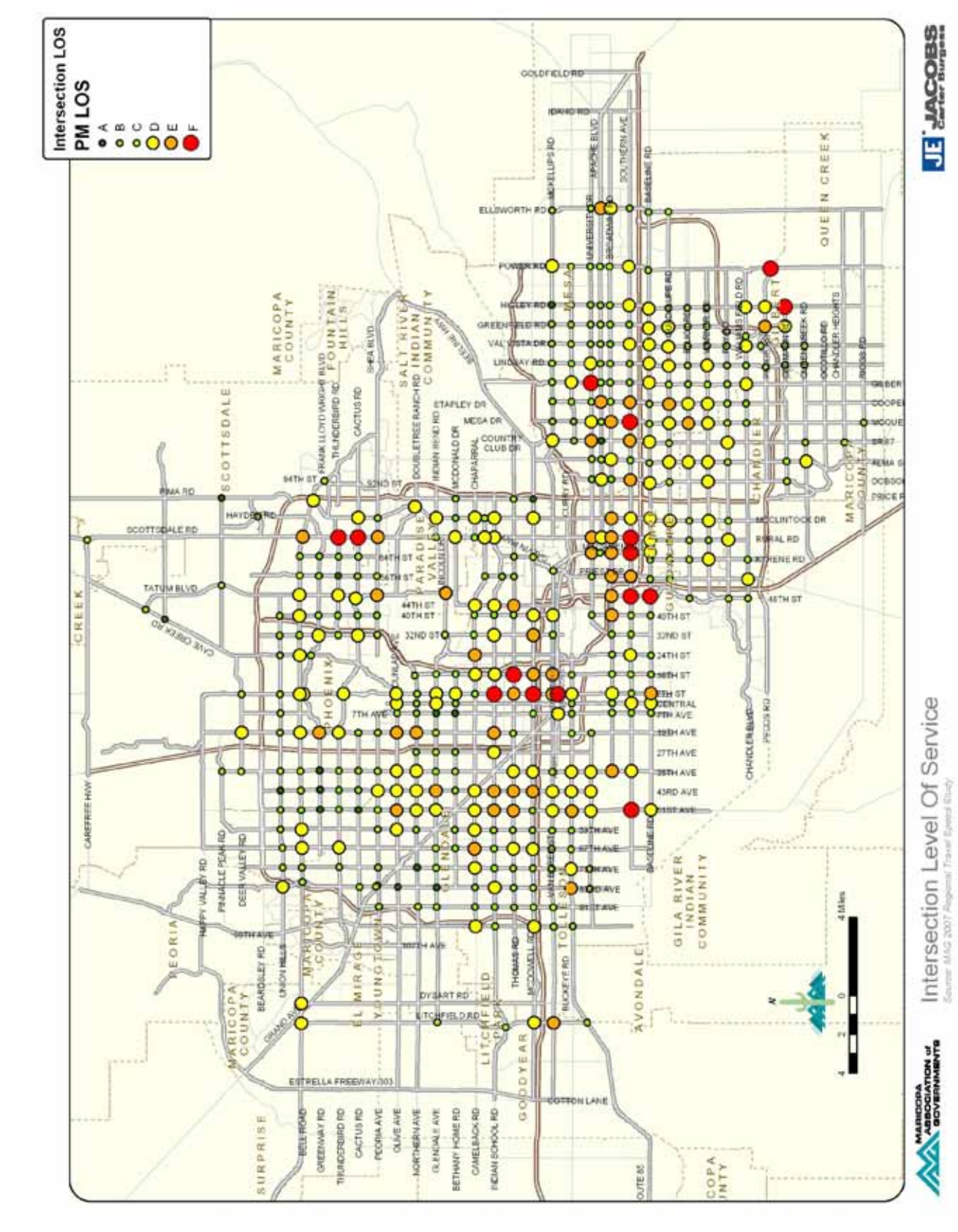


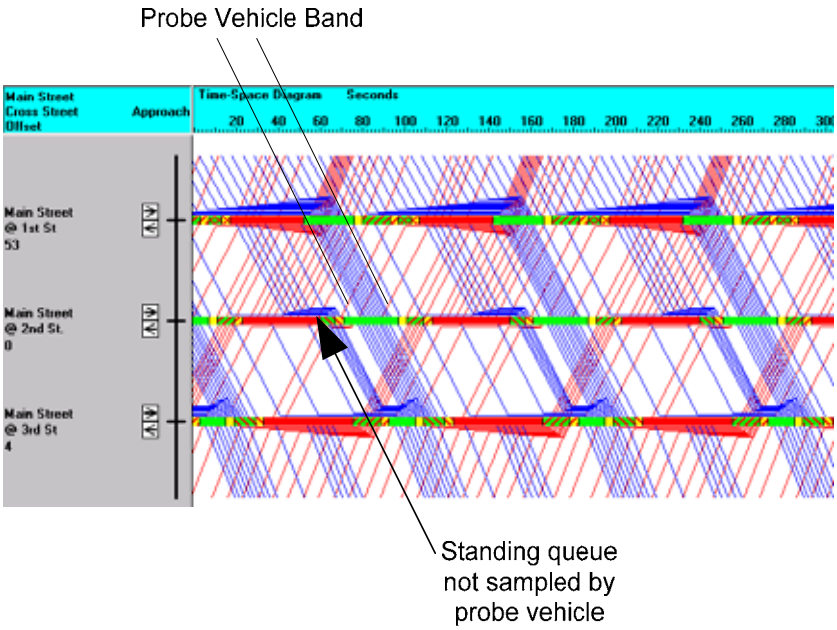
Figure 55 – Intersection LOS – PM



5.2 Queue Measurement

One of the questions that has been raised regarding probe GPS data, is "can queue length be measured." Strictly, speaking the answer to this is no, because the sampling procedure will be biased. To illustrate this point, consider the time-space diagram shown in **Figure 56**. The figure shows the queuing that occurs in a coordinated system. The blue and red lines represent the two directions on an arterial. The multi-color bands are the signal phasing and cycle lengths.

Figure 56 – Time Space Diagram



As one can observe, a probe vehicle would only sample the queue at the middle intersection during periods bounded by the bands defined by start of through green and end of through green at an upstream signal. In general, this is less then 50% of the cycle. However, it is certainly feasible to report maximum, minimum, and average queue length from the travel runs. This data would be based upon queue length observed by through arterial traffic, it does not reflect queue conditions that may occur for minor movements. Queues measurements would be subject to the following assumptions:

- The back of the queue would be defined as the point where the speed fell below 3 mph and the queue continues to the next cross street.
- Probe vehicles are uniformly distributed in the green band.

Figures 57-59 illustrates the average queue length for AM, MD, and PM, respectively.

Figure 57 – Average Intersection Queue Position – AM

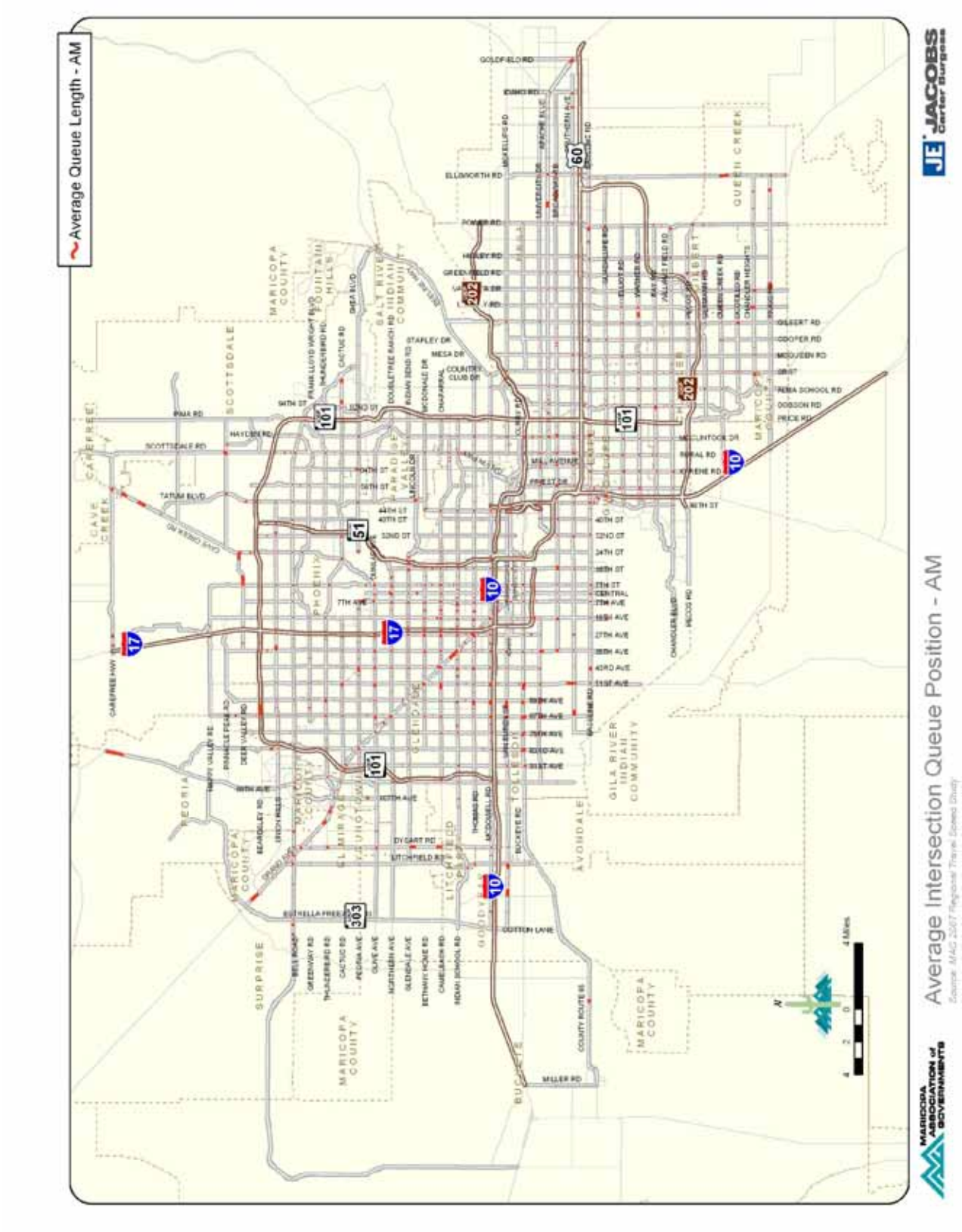


Figure 58 – Average Intersection Queue Position – Mid-Day

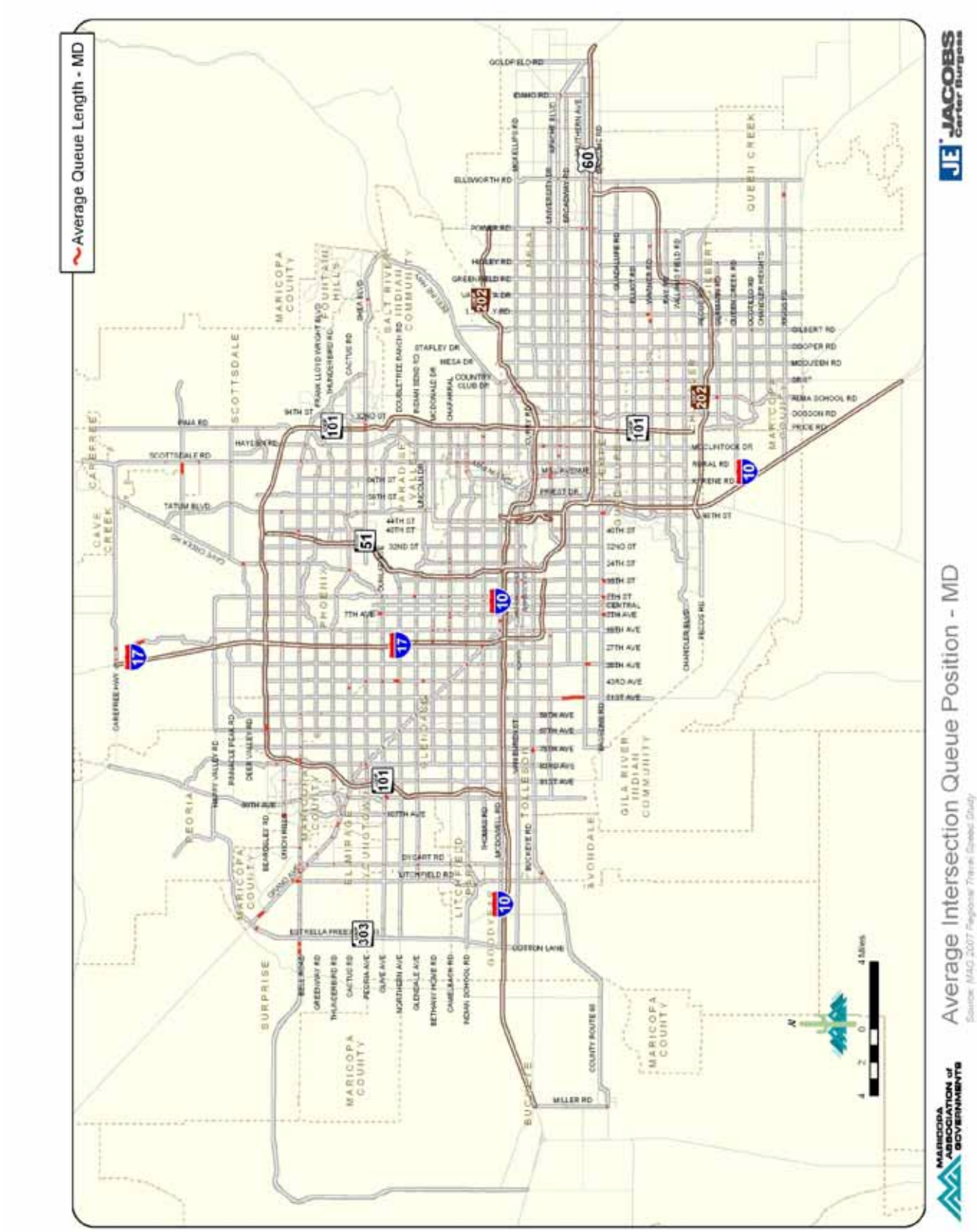
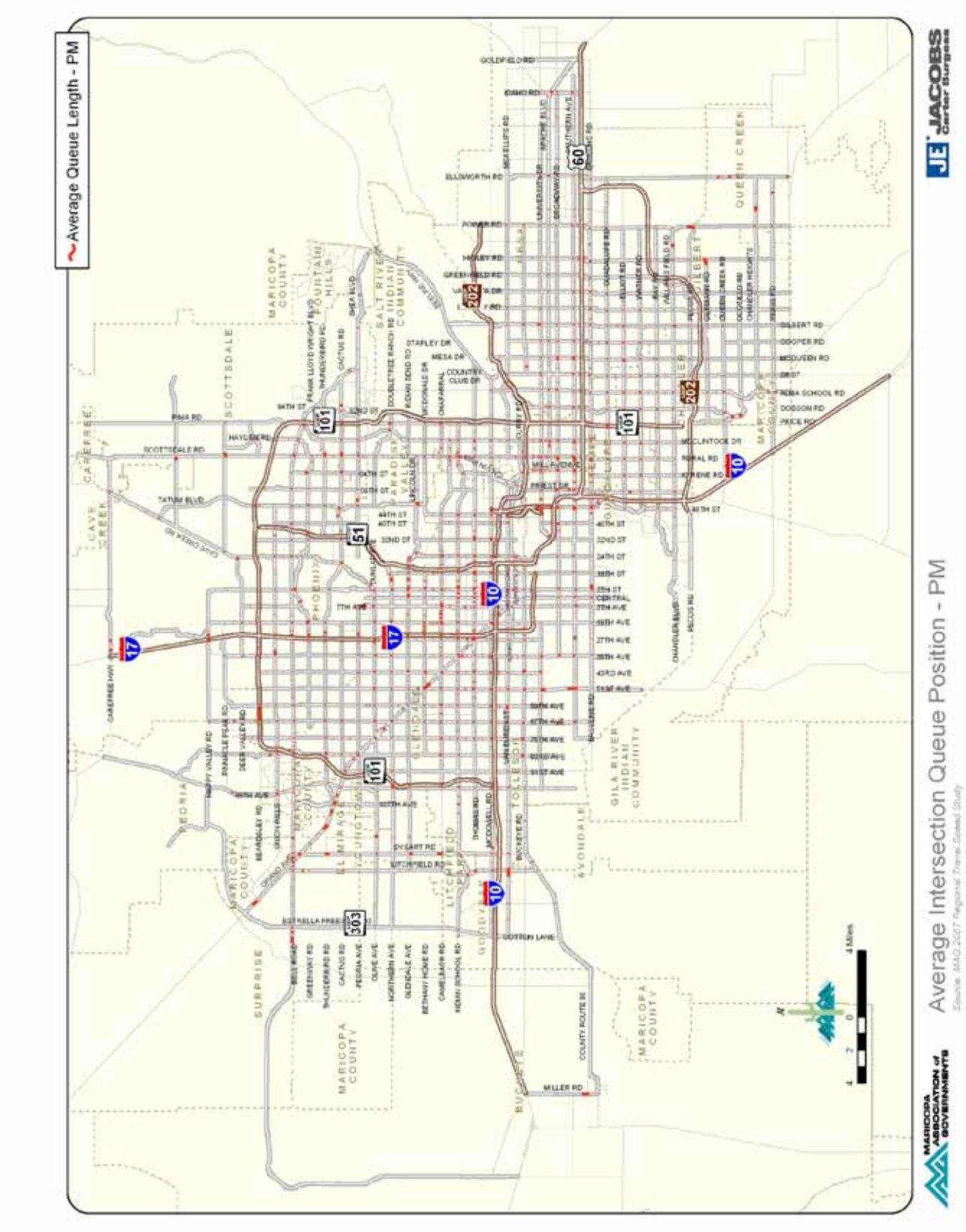


Figure 59 – Average Intersection Queue Position – PM



6.0 Historical Speed Changes

In order to compare the results to previous studies, the data needed to be modified similar to what was done in the 2002-2003 study. For example, the 1993 study used longer segments than the 2007 study, so segments in this study were combined to create the same segments as in the 1993 study.

Figures 60-67 are included for reference and depict the average speed found in the 1979, 1986, 1993, and 2002-2003 studies respectively for the PM period. **Figures 68-69** illustrates the results of the coding of the historic network and represents changes in speeds since 1993 for those roads included in both studies.

The historic results from the 1979, 1986, and 1993 were geocoded using the linear reference network created in the 2002-2003 Regional Travel Time & Travel Speed Study. This effort allowed multiple comparisons and queries in GIS. **Table 31** illustrates the changes in speed between the Cities previously tabulated in historic studies.

Table 31 – Average Speed between Central Business Districts

Average PM Peak Period/Peak Direction Speed Between Central Business Districts[1], 1966 to 2007[2]

			Speeds in Miles per Hour								Change in Speeds			
			1966	1970	1976	1979	1986	1993	2003	2007	1966 to 1993	1966 to 2003	1993 to 2003	2003 to 2007
Glendale	-	Scottsdale	33.4	31.6	29.6	26.5	26.8	25.1	40.1	28.8	-8.3	6.7	15.0	-11.3
Phoenix	-	Glendale	24.0	26.2	23.0	23.4	22.6	24.6	21.2	23.4	0.6	-2.8	-3.4	2.2
Phoenix	-	Scottsdale	25.3	27.1	22.1	26.5	22.8	28.4	32.0	26.0	3.1	6.7	3.6	-6.0
Phoenix	-	Tempe	25.8	28.4	25.1	28.3	24.4	32.7	34.2	22.8	6.9	8.4	1.5	-11.4
Tempe	-	Scottsdale	28.5	24.2	25.0	23.9	17.0	20.6	27.3	23.7	-7.9	-1.2	6.7	-3.6
Tempe	-	Mesa	32.0	30.7	25.7	25.0	19.6	29.3	25.1	23.0	-2.7	-6.9	-4.2	-2.1

[1] CBD Locations:
Glendale-Glendale Avenue and 59th Avenue
Mesa-Main Street and Center Street
Phoenix-2nd Avenue and Washington
Scottsdale-Scottsdale Road and Indian School Road
Tempe-University Drive and Mill Avenue

[2] Speeds for 1966, 1970, 1976, 1979, 1986 and 1993 are from the 1993 Study of Travel Speed and Delay in the MAG Region.

Due to limitation of historical data, only above CBD travel speed results can be presented

Figure 60 - Average Freeway Speed 1979 – PM

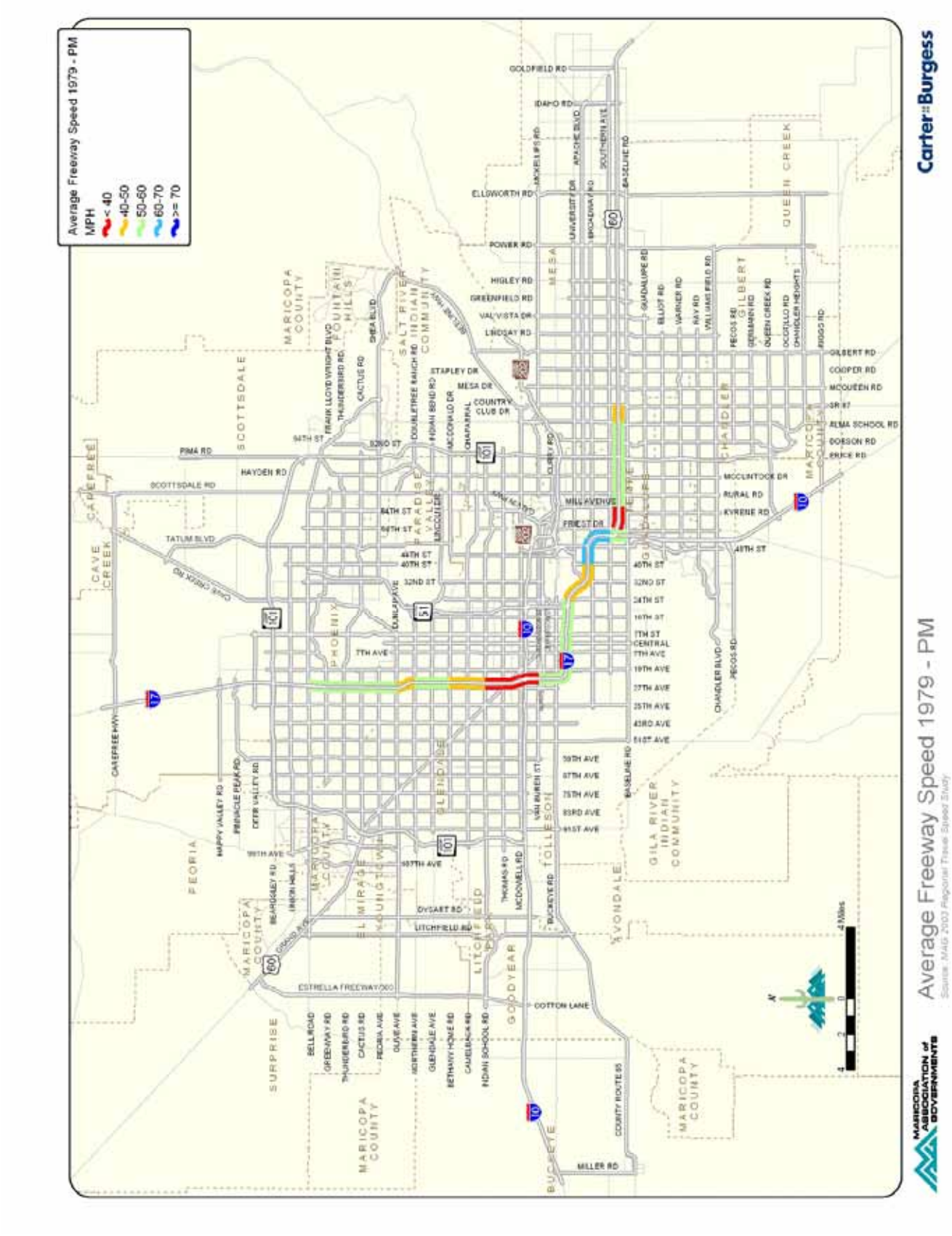


Figure 61 - Average Arterial Speed 1979 – PM

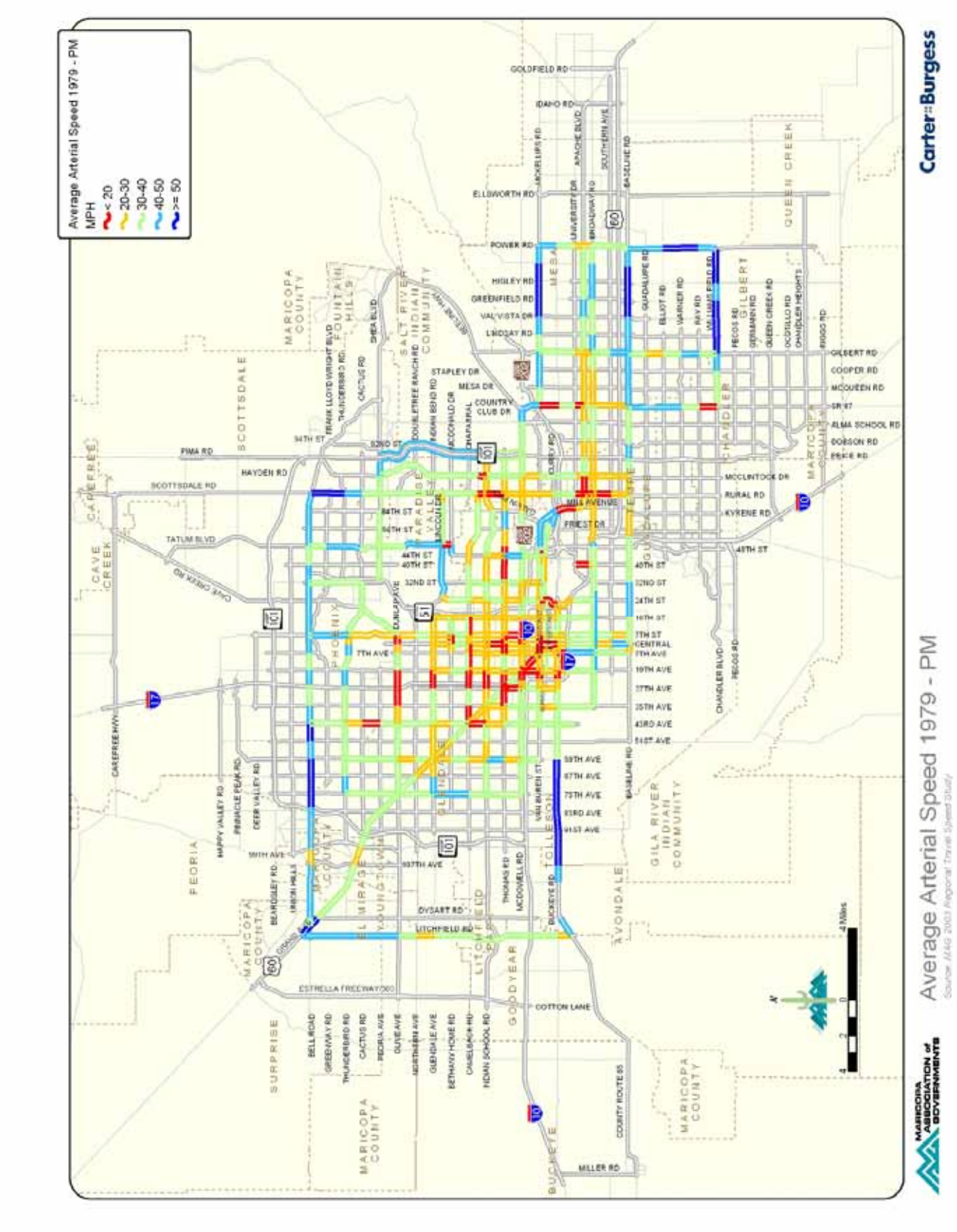


Figure 62 - Average Freeway Speed 1986 – PM

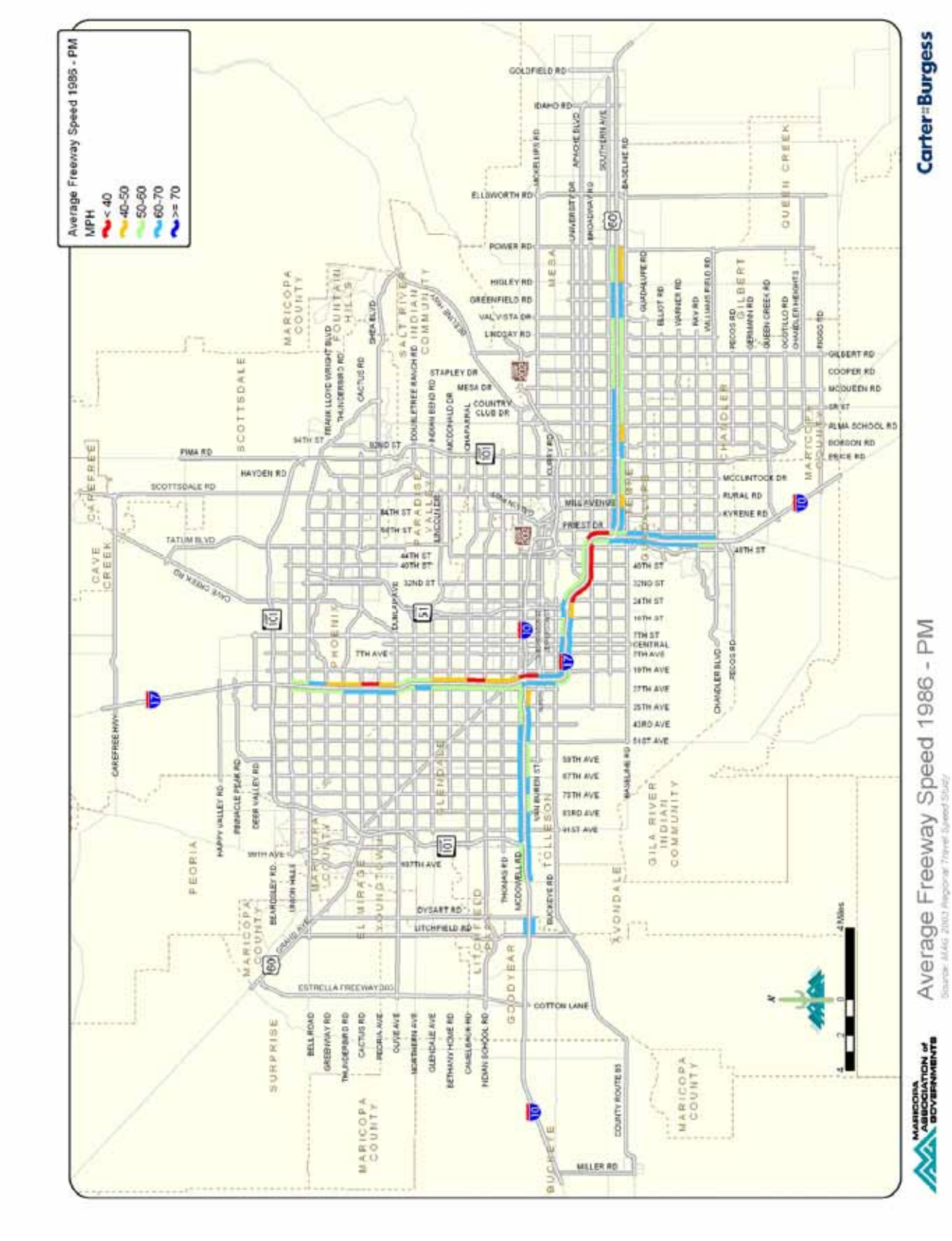


Figure 63 - Average Arterial Speed 1986 – PM

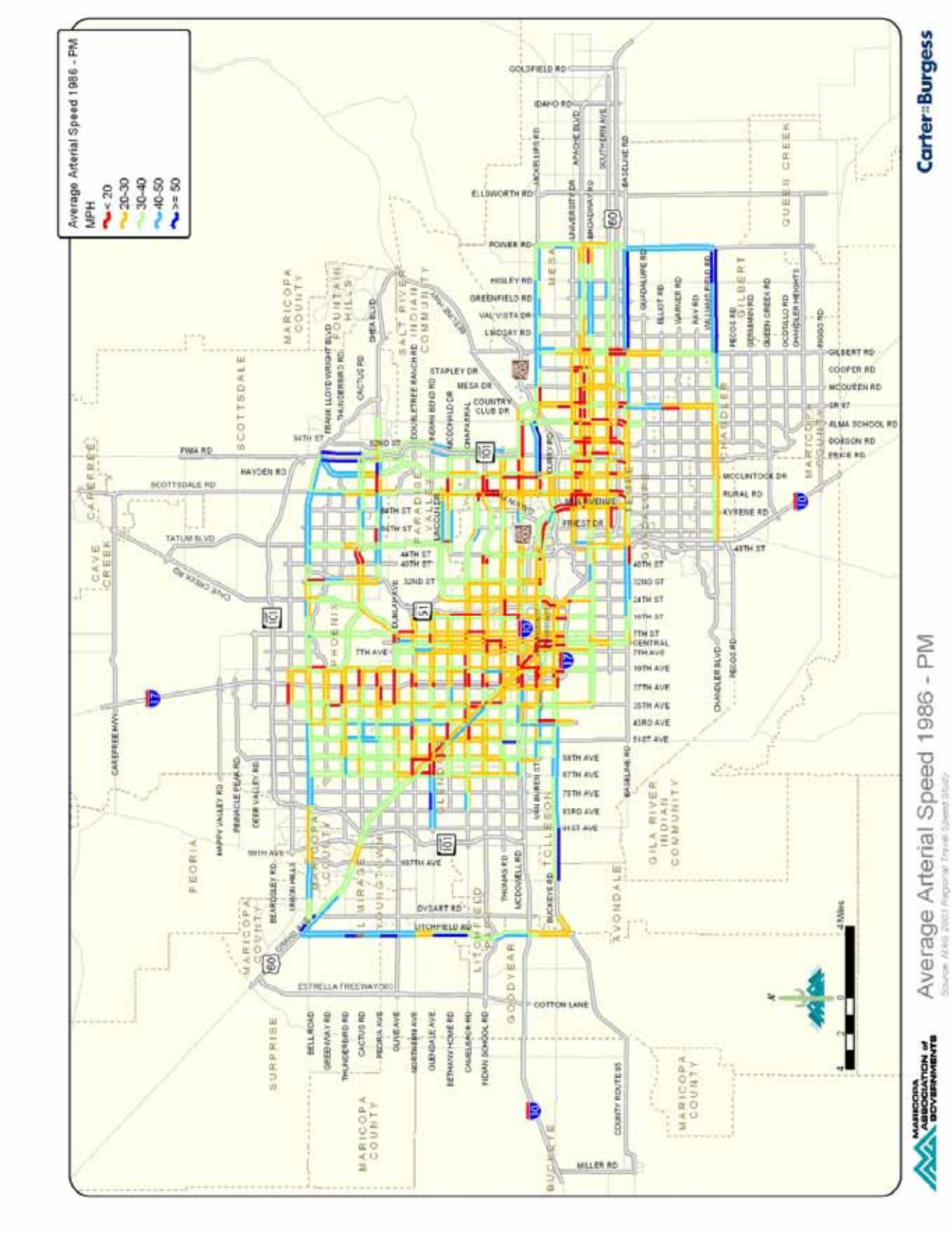


Figure 64 - Average Freeway Speed 1993 – PM

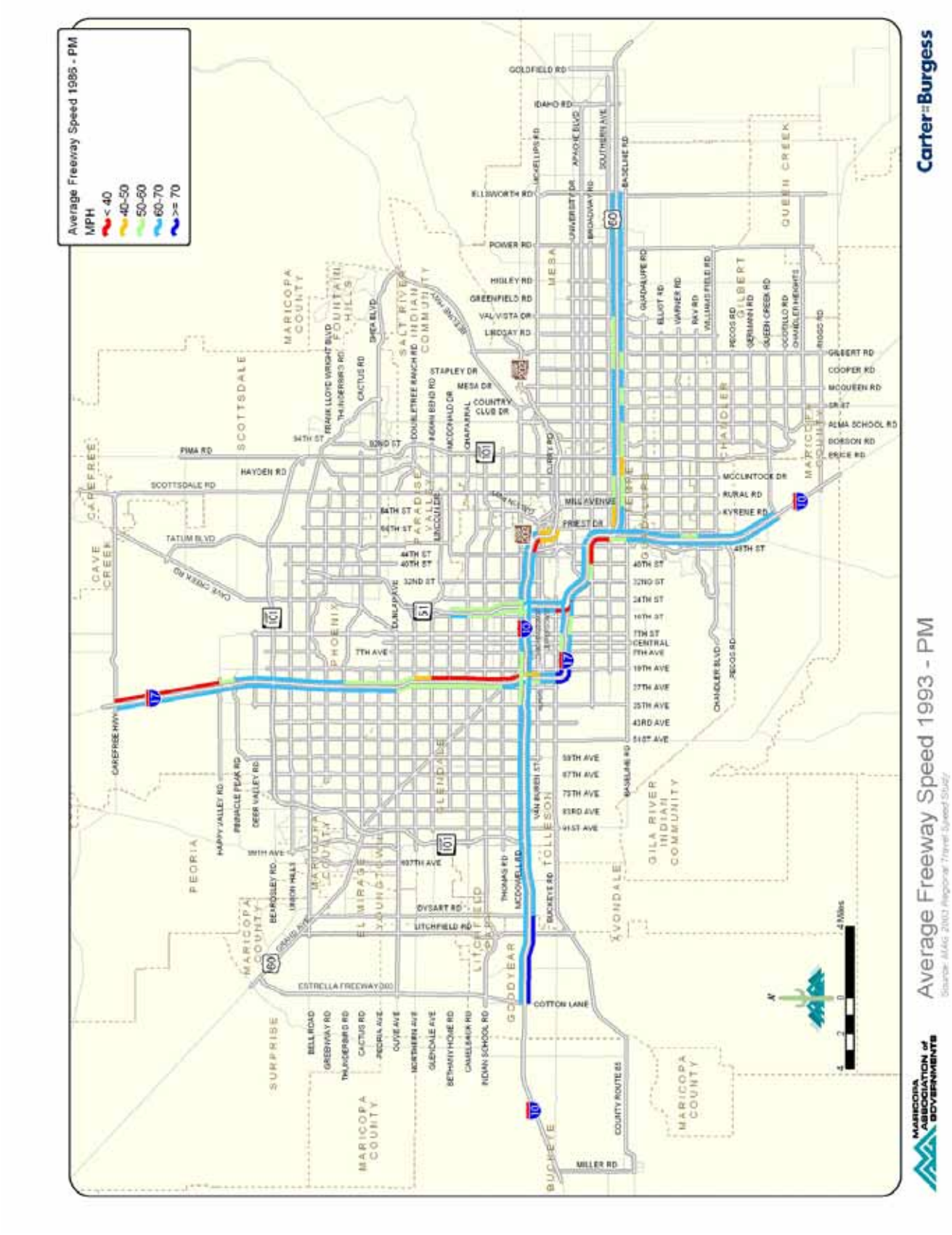


Figure 65 - Average Arterial Speed 1993 – PM

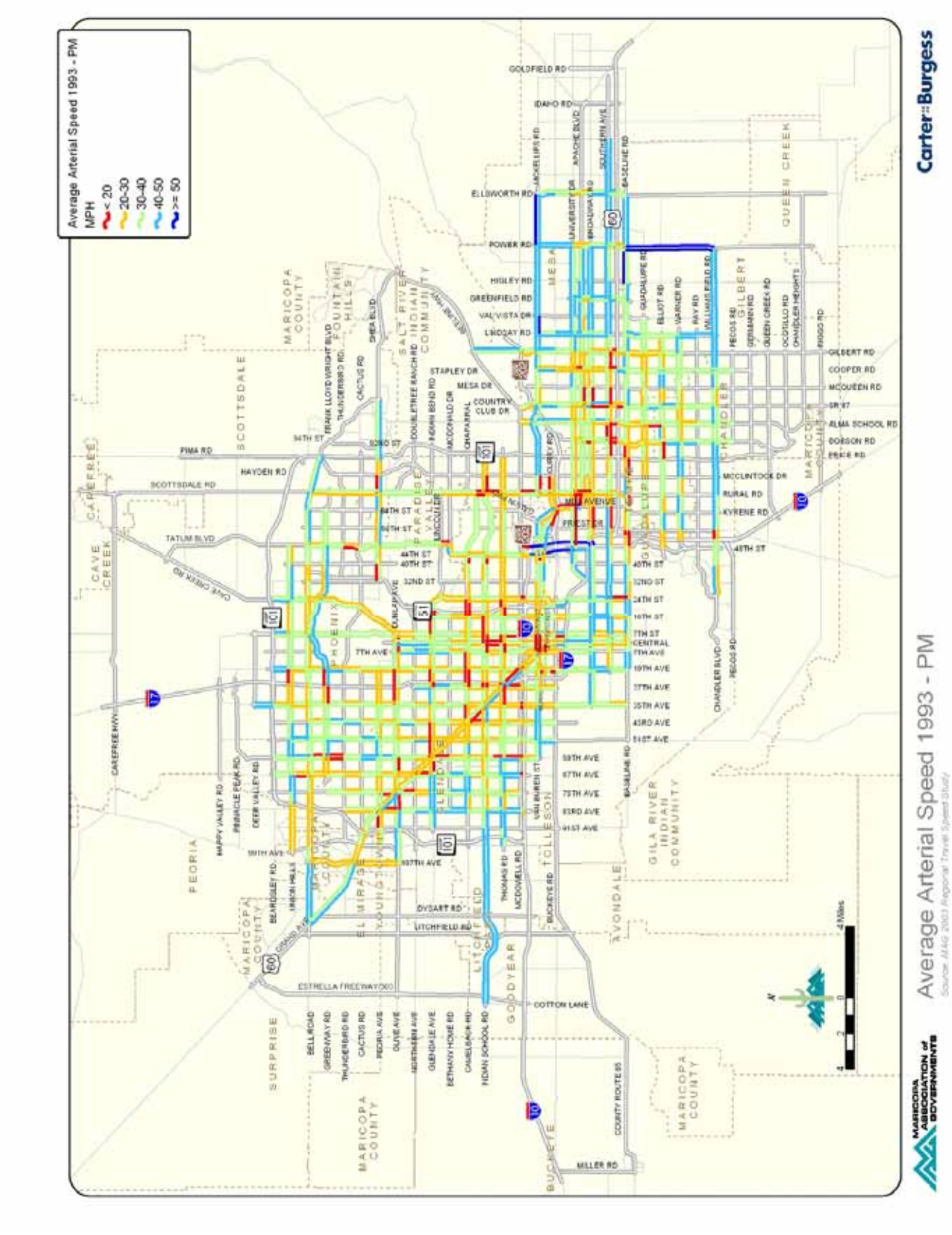


Figure 66 - Average Freeway Speed 2003 – PM

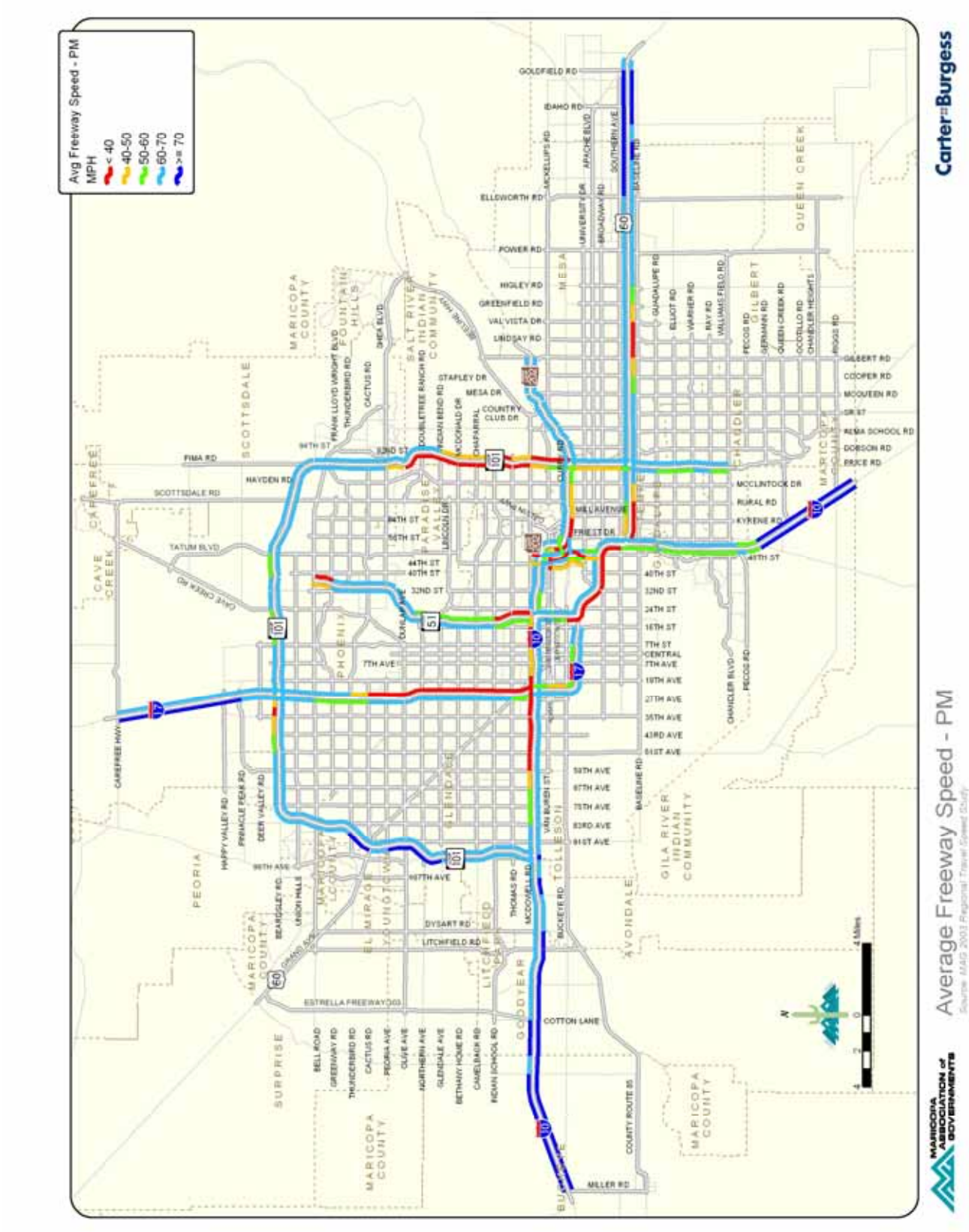


Figure 67 - Average Arterial Speed 2003 – PM

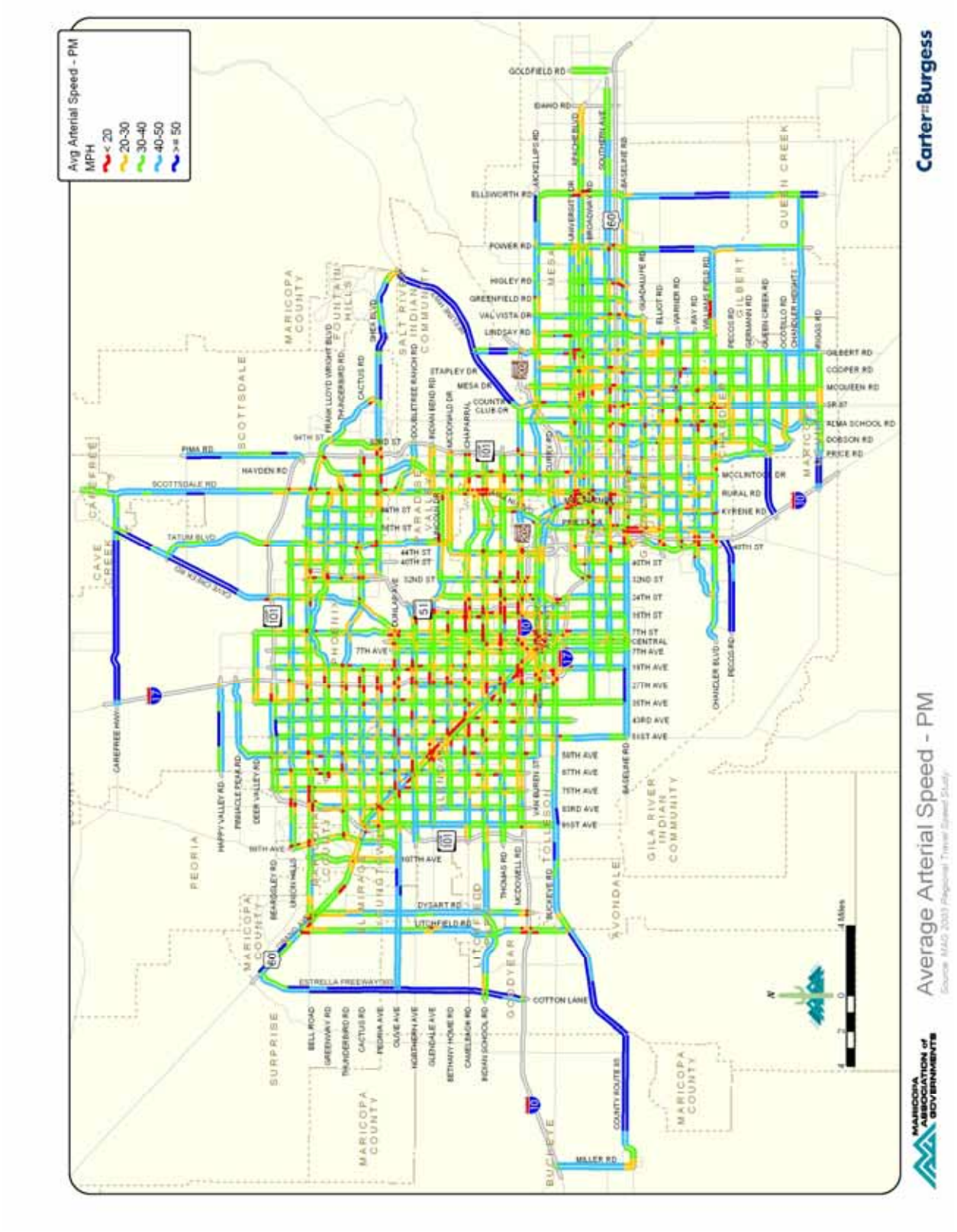


Figure 68- Change in Average Freeway Speed 2003 to 2007 PM

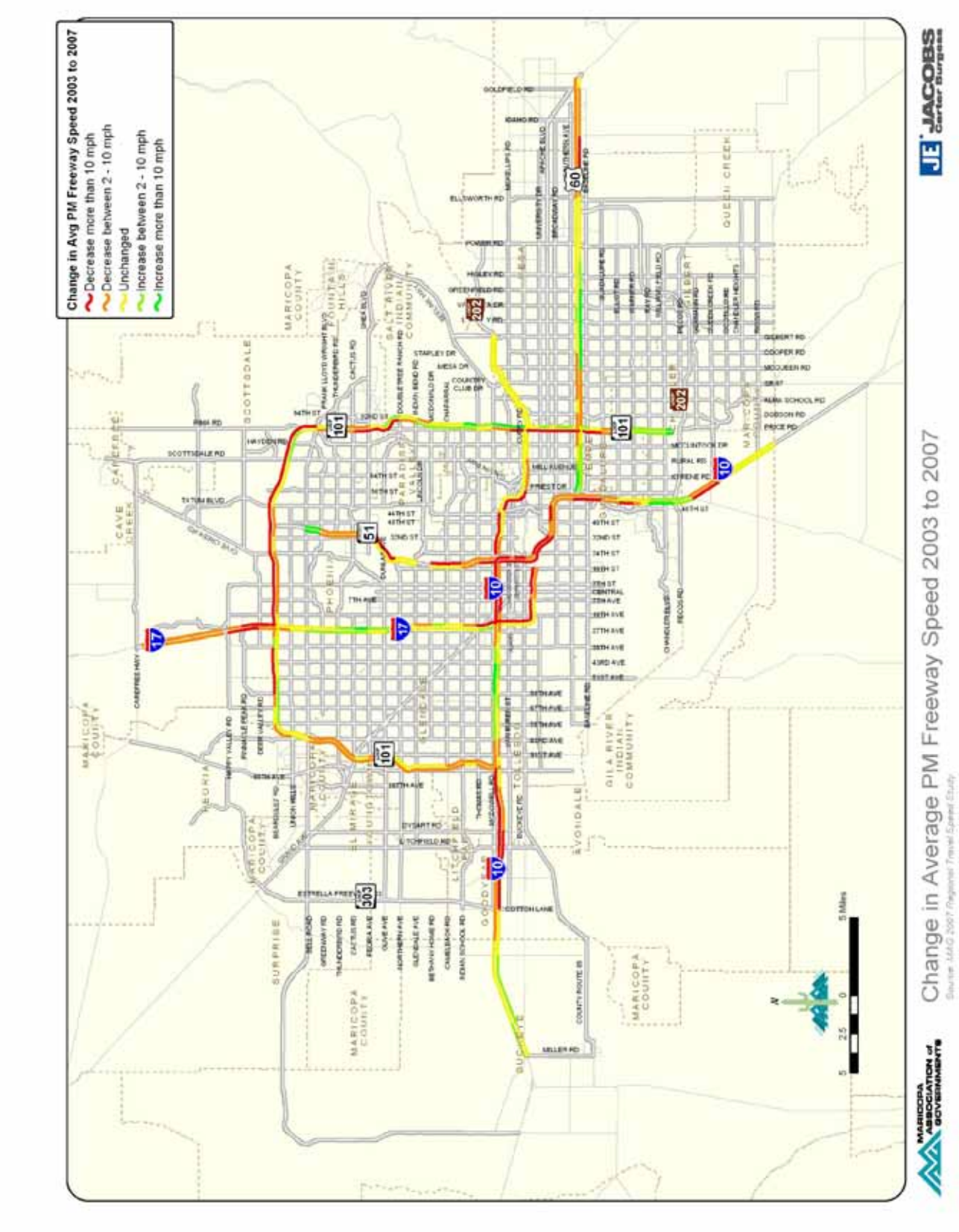
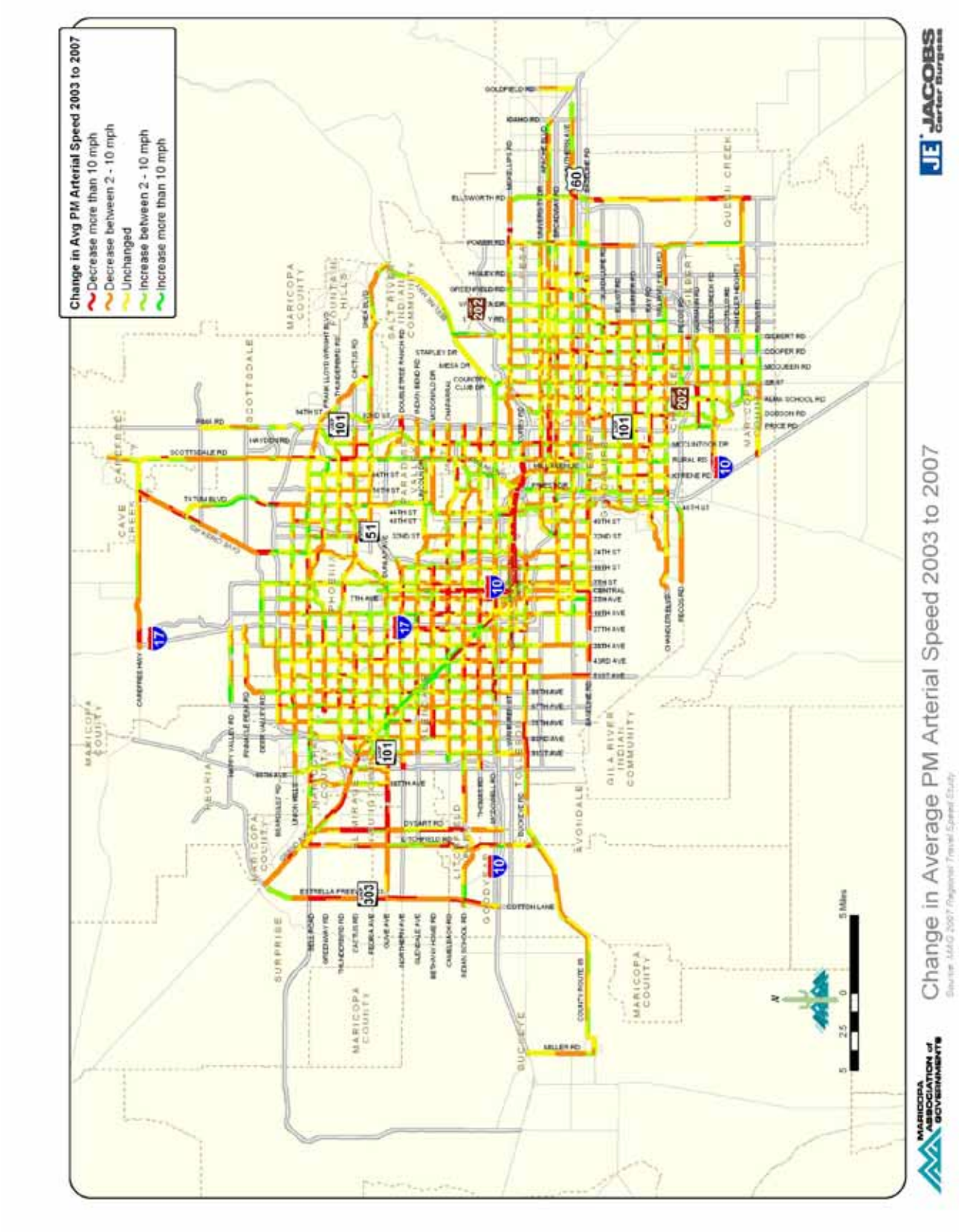


Figure 69- Change in Average Arterial Speed 2003 to 2007 PM



REFERENCES

1. "Estimating Intersection Control Delay Using Large Data Sets of Travel Time from a Global Positioning System." Journal of the Transportation Research Board: Transportation Research Record 1917, Transportation Research Board, National Research Council, Washington, D.C., p. 18-27, with Bullock, D., Schlappi, M., 2005.